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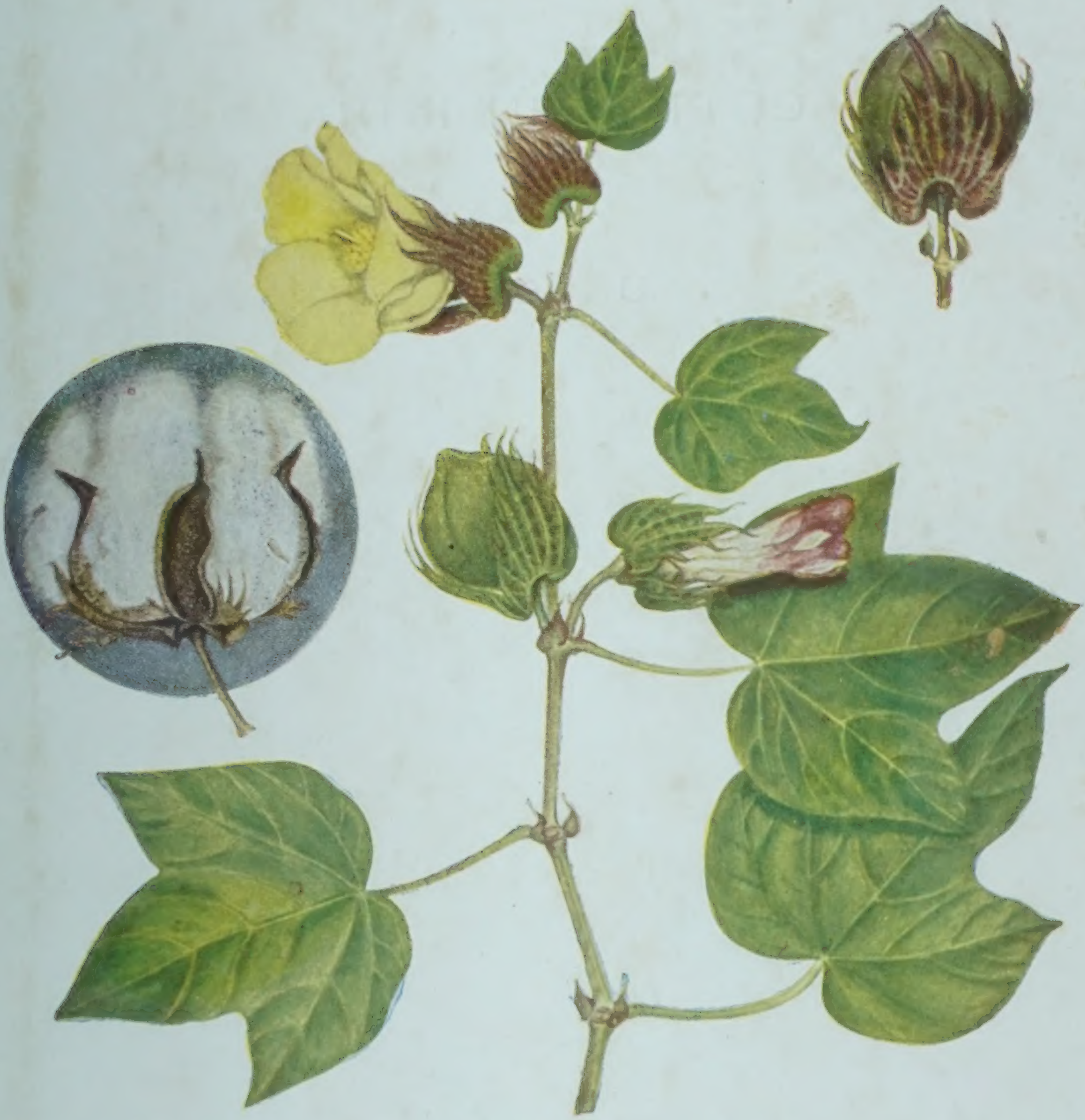
COTTON IN INDIA

A MONOGRAPH



GOSSYPIUM HIRSUTUM *RACE* LATIFOLIUM

(*Reproduced from Wealth of India—Raw Materials, Vol. IV, CSIR, New Delhi*)

COTTON IN INDIA

A MONOGRAPH

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Cotton in India...

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INTRODUCTION

On the suggestion of its Policy Sub-Committee, the Indian Central Cotton Committee at its meeting held in February, 1956, decided to publish a Monograph on Cotton with a view to making available to the various educational and research institutions as well as the enlightened cotton growers and others interested in the subject, a comprehensive account, in simple language, on cotton in all its aspects on a regionwise basis. Pursuant to this decision, a small Sub-Committee discussed at length the divergent needs that the Monograph would serve and other aspects concerning its publication and recommended that it should consist of four volumes, comprising the following chapters :

Volume I : History of Cotton; Climate and Soils; Taxonomy; Morphology; Embryology; Breeding; Cytology; and Genetics.

Volume II : Physiology; Agronomy; Diseases; Insect and Mite Pests; and Seed Multiplication and Distribution.

Volume III : Technology; Ginning and Pressing; Marketing; Consumption of Cotton seed; Consumption of Cotton Lint; Legislative Measures; and Exports and Imports.

Volume IV : Northern *hirsutum-arboreum* Region; Central *arboreum* Region; Southern *hirsutum-arboreum* Region; Central *hirsutum-arboreum-herbaceum* Region; Western *herbaceum* Region; and Eastern Region.

Accordingly, the First Volume was issued in February, 1960, and the Second Volume was brought out in July of the same year. It is a matter of deep gratification that it has been possible to issue the Third Volume within so short a time which is largely due to the unstinted co-operation received from the various authors who contributed the material for this volume.

The contents of this volume include chapters on Technology, Ginning and Pressing, Marketing, Consumption of Cotton seed, Consumption of Cotton Lint, Legislative Measures and Exports and Imports. The Indian Central Cotton Committee is grateful to Dr. C. Nanjundayya, Dr. R. L. N. Iyengar, Shri W. R. Natu, Dr. M. B. Ghatge, Dr. K. S. Murti, Shri Chimanlal B. Parikh and Mr. D. N. Mahta for their kind co-operation and the pains they have taken to present the material in a comprehensive manner in the chapters contributed by them.

I am thankful to the Council of Scientific and Industrial Research for their kind permission to reproduce the coloured plate *Gossypium hirsutum* race *latifolium* appearing in the article on *Gossypium* Linn. of the Wealth of India—Dictionary of Raw Materials and Industrial Products and to the East India Cotton Association Ltd. for supplying two photographs relating to the marketing of cotton.

The jacket of this volume was designed by Shri N. S. Bisht, Director of Art, Indian Council of Agricultural Research, whose help is acknowledged with thanks.

I must also express my gratitude to the members of the Indian Central Cotton Committee, particularly the Vice-President, Shri Madanmohan R. Ruia, Shri R. G. Saraiya, Shri Chimanlal B. Parikh and Shri Chunilal B. Mehta for their valuable suggestions and encourangement in the publication of the Monograph. Thanks are also due to the staff of the Committee in the Monograph Section for their zeal in completing this volume.

Last but not the least, I must place on record my profound gratitude to the President of the Indian Central Cotton Committee, Dr. M. S. Randhawa, but for whose sustained interest, encouragement and guidance, the publication of the Monograph would not have materialised.

B. L. SETHI
Secretary
Indian Central Cotton Committee

Bombay
October 1960

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CHAPTER I

TECHNOLOGY

Although the wild species of cotton plant has been in existence from ancient times and archaeological evidence shows that cotton cloth was made in India as far back as 5,000 years, scientific research on cotton—both agricultural and technological — commenced only by about the beginning of this century. A great deal of attention is being devoted towards the improvement of the quality of cotton and reduction of cost of production, especially in recent years, when man-made fibres are threatening to replace cotton in several fields. It is, however, noteworthy that, despite tremendous human efforts to produce artificial fibres which would serve for most of the end-uses of cotton at a relatively low cost and thus avoid dependence on the vagaries of nature, cotton, being a versatile fibre, has maintained its predominant position amongst textile fibres.

Cotton fibre possesses some special characteristics which are difficult to introduce in the man-made fibres. While, on the one hand, a great deal of research is being directed to produce man-made fibres having the desirable character or characteristics of natural fibres, on the other, considerable work is being carried out not only for evolving new and improved varieties of cotton by agricultural methods, but also for producing the desired fibre characters by chemical and other treatments. This involves an exhaustive study of the physical and chemical properties of the cotton fibre, their dependence upon both its macro- and micro-structures and the effect of various agricultural operations on the genetic and environmental conditions of growth.

The agricultural aspects of cotton research are dealt with in the other volumes of this Monograph. The technological aspect will be briefly described in this chapter.

Cotton technology is indeed a comprehensive phrase which involves the application of various pure sciences. Its importance to the cotton breeder and the manufacturer cannot be over emphasised. In the process of evolving new and improved varieties, the cotton breeder has to employ a yard-stick for the measurement of those fibre properties which are demanded by the spinner, and it is in this respect that cotton technology is of immense value to the breeder.

A knowledge of the development of the fibre is necessary to be able to gauge the influence of the various agricultural factors operating during the growth of the cotton plant. Next comes the question as to how and to what extent they affect the fibre characteristics which obviously determine the subsequent technological behaviour in the process of conversion from fibre to fabric. These, necessarily, require methods and apparatus for determining rapidly and accurately the important fibre properties. As the monetary value of a type of cotton mainly depends on its quality, estimation of the latter is essential not only to the cotton breeder, but to trade and industry also. Finally, the wide range of fibre properties among the world cottons and the variability even within a cotton make it imperative for persons dealing with cotton to have some knowledge of elementary statistics and its chief applications to cotton technology, for a proper interpretation of the experimental data.

In the following pages, a brief account is given of some of these sections of cotton technology. It may, however, be mentioned that it is difficult to do justice to a vast subject of this kind in the brief space available here, but it is hoped that the present account would assist the readers in getting a comprehensive idea of the knowledge that has been collected so far, and in understanding the results that may be made available by further researches in this field.

DEVELOPMENT OF COTTON FIBRE

The cotton fibre is formed by the external protrusion of a single cell from the outer covering, or the epidermis, of the cotton seed. It first emerges as a slight swelling of the outer wall of the epidermal cell on the day of flowering, and thereafter, every day it beigns to elongate (Fig. 1). Not all the cells of the epidermis develop into fibres; some form normal fibres, some others develop into short thick fibres, called 'fuzz', while the rest remain as mere epidermal cells. Microscopic examination of the ovules, before the fertilisation of the blossom, shows the outer layer to be composed of undifferentiated epidermal cells. The period after fertilisation is one of rapid growth in the epidermal layer; this is characterised by cell division rather than enlargement of the cells. Differentiation of epidermal cells into fibre cells, according to Balls (1915, 1928), is determined by environmental conditions on the day of flower opening, and no further differentiation of fibre cells takes place thereafter. Later investigations have shown that the differentiation of fibre cells continues much later than the date of flowering, extending up to two or three weeks.

On the first day of flower opening, most of the differentiated fibres, appearing as small protrusions, are seen at the broad or chalazal end of the seed, while on the second, third and subsequent days further protrusions appear, indicating that the pattern of these protrusions spreads towards the pointed or micropylar end of the seed. It has been suggested that the fibre cells that sprout from the first to the fifth day develop into commercial lint fibres, while those which appear later develop into fuzzy fibres, which form a dense entangled mat that adheres closely to the seed surface.

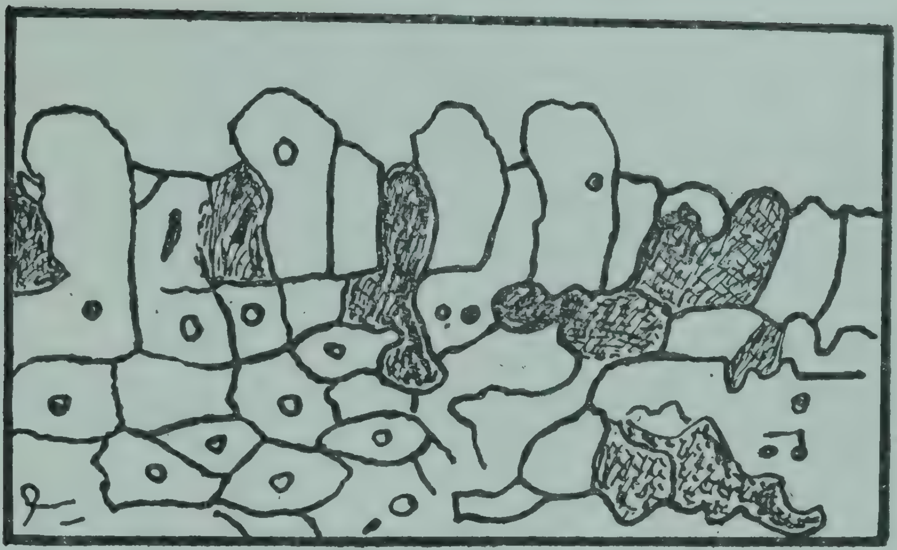


Fig. 1. Section of Cotton Seed with Fibre Protrusions Emerging from the Epidermis

As mentioned earlier, the epidermal cell protrudes as a fibre cell on the day of flower opening and for a few days afterwards. As the boll develops, this protrusion continues to elongate in a direction radial to the surface of the seed. The sprouting fibre would have attained its maximum diameter even on the day it originates, and the elongation is effected by intercalation of patches in the tube from the growth centre. During the progress of elongation, the protoplasm of the cotton fibre is enclosed in a sheath like membrane, called the primary wall, which is made up of a cellulose layer of about half a micron in thickness. The fibre at this stage appears as a long, delicate tube with an extremely thin wall. The increase in length continues for 20 to 40 days, depending on the variety of cotton and the environmental conditions during the growth. The rate of elongation of the fibre has been found to be about one millimetre per day in Egyptian (*Gossypium barbadense*) varieties and 1·2 to 1·9 millimetres per day in Cambodia (*G. hirsutum*) cotton. The total length which a fibre attains depends upon the variety of cotton, ranging, on an average, from about half an inch in some short staple Indian cottons to about 2·5 inches in the case of Sea Island cottons.

All the fibres cannot stand out radially on each seed within a boll; thousands of them are to be accommodated within the small space available inside a boll, and so, they follow a zigzag pattern (Fig. 2).

The elongation of the fibre stops almost abruptly at the end of the half maturation period, and then thickening begins. Thus, there are two distinct phases in the development of cotton fibre, viz: (*i*) lengthening phase; and (*ii*) thickening phase. The long thin tube that has completed its elongation gets filled up centripetally by the deposition of cellulose inside. This is called the secondary thickening and takes place in concentric layers, one on each day, until the development of the boll is completed. The number of layers thus deposited varies with the variety and environmental conditions. These layers

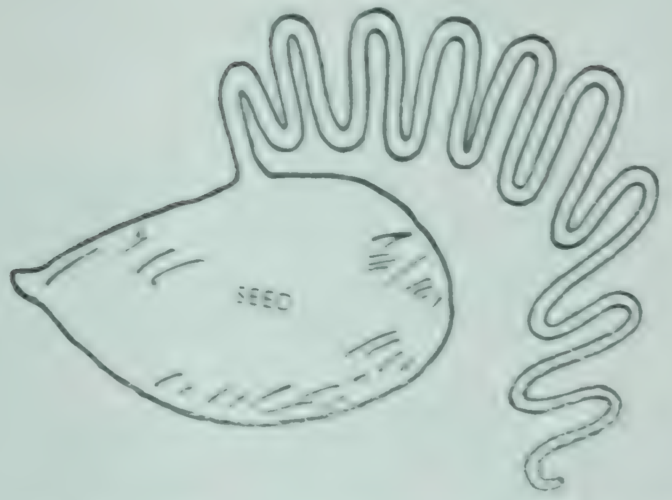


Fig. 2. Folded Cotton Fibre as it Grows Inside the Boll

have been called 'growth rings', each being, on an average, about 0·4 microns thick (Fig. 3). All the fibres do not get a uniform degree of secondary thickening; a few get more than the others. This accounts for the variation in the degree of maturity of different fibres even on the same seed.

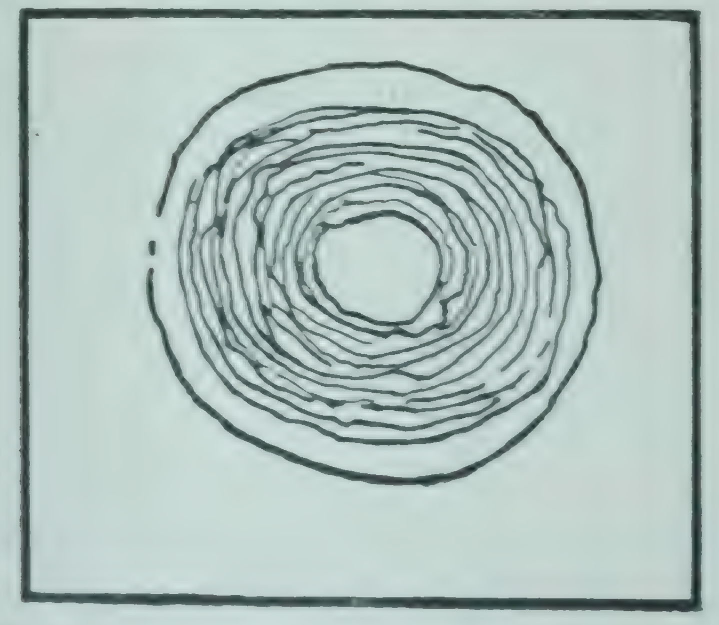


Fig. 3. Cross-Section of Cotton Fibre Showing Growth Rings

When the boll ceases to develop, it bursts open due to inside pressure, and dehydration of its contents commences. The dehydration may be completed in 15 to 25 days. As a result, the fibre collapses and the ultimate cross-section changes from a nearly cylindrical to a bean or elliptical shape. Further, it gets twisted at several places along its length. These twists are termed convolutions, which are characteristic of the cotton fibre. The residue of the proteinaceous solids is deposited in the central canal of the fibre, which is called the 'lumen'.

There are thousands of lint fibres on each seed and their number varies considerably from one variety to another as shown in Table 1.

TABLE 1. AVERAGE NUMBER OF FIBRES ON A SEED

Cotton	Botanical species	Number of fibres	Authority	Source
China cotton	*G. arboreum* race *sinense* Hutchinson and Stephens	1,200-3,300	Leake	Turner (1929)
Sea Island varieties:				
H. 23, V. 135, F_1	*G. barbadense*	11,700-16,400	Burd	
310N, 77G (Nubari type)	*G. barbadense*	8,000	Balls	
K. 22, J. N. 1., A. 19, Mollisoni	*G. arboreum* race *bengalense*	5,000-6,700		Iyengar and Turner (1930)
Umri Bani, N.14, Karunganni	*G. arboreum* race *indicum*	2,500-5,200		
Gadag 1, 4F, 285F, 289F, C.A.9, Co.1.	*G. hirsutum*	7,200-14,900		

STRUCTURE OF COTTON FIBRE

The structure of the cotton fibre may be discussed under three heads: (*i*) morphological structure, that is, its appearance under the microscope; (*ii*) molecular structure, showing the nature and formation of cellulose molecules inside the fibre; and (*iii*) fine or X-ray structure, indicating the scheme or pattern of arrangement of these cellulose molecules.

MORPHOLOGICAL STRUCTURE

The cotton fibre, when viewed under a low power microscope, appears as a translucent, collapsed and flattened tube, characterised by natural twists, called convolutions (Fig. 4). It is relatively broad at the base and more or less tapering at the tip or the apex. The basal end of the fibre has an irregular shape. The distinguishing feature of the tip of the fibre is the absence of both the lumen and convolutions, and in some fibres, these attenuated portions are of considerable length. Other features of the cotton fibre are the presence of fissures, corrugations, pits and abnormalities like kinks, spurs, knots, etc., along its length. The causes of these deformations are not yet fully understood, but it has been suggested that they are the result of pressure in the boll during maturation. The confining space of the boll sets up resistance to extending fibre, forcing it to lap back for small distances upon itself, thus producing characteristic fissures and buckles. Chemical and bacterial attacks often appear to start along these lines. Farr (1934), in a study of these abnormalities and the density of the fibre mass within the boll, observed fewer abnormalities in fibres from cotton with low boll density than in the case of fibres from cotton with high boll density.

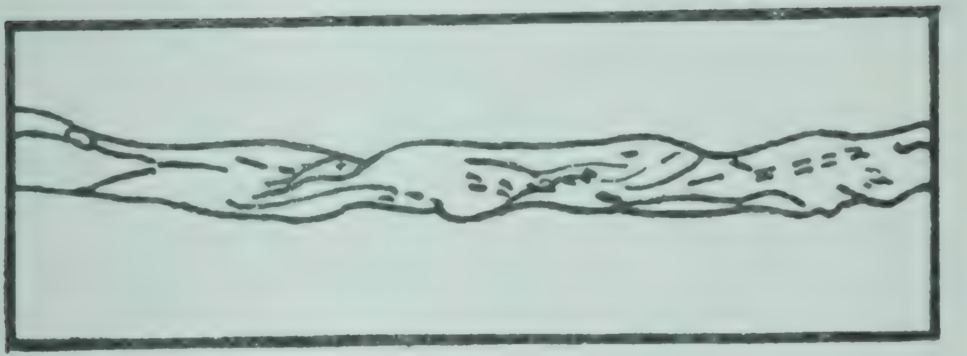


Fig. 4. Longitudinal View of Cotton Fibre as seen Under a Microscope

The cotton fibre is a single cell, which is 2,000 to 3,000 times longer than it is broad. It may be mainly divided into three regions, viz: (*i*) primary wall, which delimits the length and fineness of the fibre; (*ii*) secondary wall, which is the main cellulosic body of the fibre; and (*iii*) lumen or central canal, which contains the residue of the protoplasmic fluid of the cell (Fig. 5).

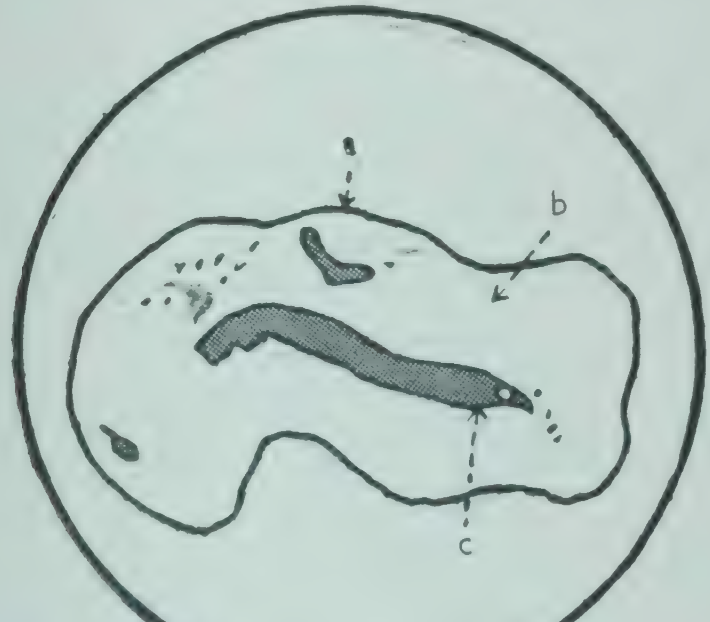


Fig. 5. Cross-Section of Cotton Fibre. a. Primary Wall, b. Secondary Wall, c. Lumen

Primary Wall. The primary wall is enveloped by the cuticle which contains a mixture of fats, waxes and pectins. Although closely and firmly attached to the primary wall during its growth, the cuticle is not an integral part of it, but it plays a major part in the surface attributes of the fibre. The primary wall is an elastic membrane which swells to the maximum extent in 18 per cent. caustic soda, but if it is swollen beyond this limit in cuprammonium hydroxide or cupriethylene diamine, the wall ruptures. The primary wall is more resistant to the action of the solvent than the secondary wall. Before the secondary cellulose deposition takes place, the primary wall does not show the typical cellulose reactions, unless it is freed from non-cellulosic contents and purified. On purification, it gives the characteristic microchemical reactions and X-ray pattern of cellulose. It is, however, not definite whether this cellulose is identical with the secondary thickening.

Under the microscope, neither the raw nor purified primary wall shows any striations or definite sturcture, but appears like a cellophane sheet. In polarised light, the raw wall exhibits the striations only to a slight degree. However, if it is stained, whether in the raw or purified state, with congo red or zinc chloriodide and observed between crossed nicols, a criss-cross matty structure becomes visible, the interweaving fibrils lying at an angle of about 70° to the fibre axis and frequently anastomosing with each other. Further, in addition to these left hand and right hand spirals, the existence of a third orientation in the cellulose structure of the primary wall, which is transverse to the fibre axis, was observed by Anderson and Kerr (1938). This fibrillar structure seems to be uniform throughout the primary wall with no reversals in the system.

Recent studies with the help of the electron microscope, with a magnification of about 100,000, have revealed that the outer surface of the primary wall exhibits an interwoven fabric structure in which the fibrils are axial, whereas the inner surface has the fibrils in transverse direction. These fibrils vary in diameter from 100 Å to 400 Å. Occurrence of layers in the net work of the primary wall has been noticed and three such layers have been observed in a three-day old Rowden cotton fibre.

The primary wall of a young fibre is about 0·5 micron in thickness, but it is about 0·1 micron thick in a mature fibre. A membrane of such small dimensions is unlikely to make any significant contribution to the tensile strength of normal fibres, though it is known to influence the swelling behaviour of the secondary cellulose. Nevertheless, it is the primary wall that comes in immediate contact with the processing environments and, as such, is involved in frictional effects, wetting, dyeing, etc. The structure and behaviour of this thin membrane are, therefore, important, notwithstanding the fact that it constitutes only about three per cent. of the fibre.

Secondary Wall. The secondary wall is the main cellulose body of the fibre, whose nature and behaviour determine all its properties. The structure of this wall can be seen by swelling the cotton fibre in sodium hydroxide, dilute cuprammonium hydroxide or cupriethylene diamine and observing it under the microscope, when the fibre appears like a 'balloon' with constrictions at invervals (Fig. 6). This balloon-like formation is due to the rupture of the primary wall at places under the pressure of the expanding cellulose inside. The primary wall can be seen peeling off the outside of the balloon or clinging to the constricting collar between them.

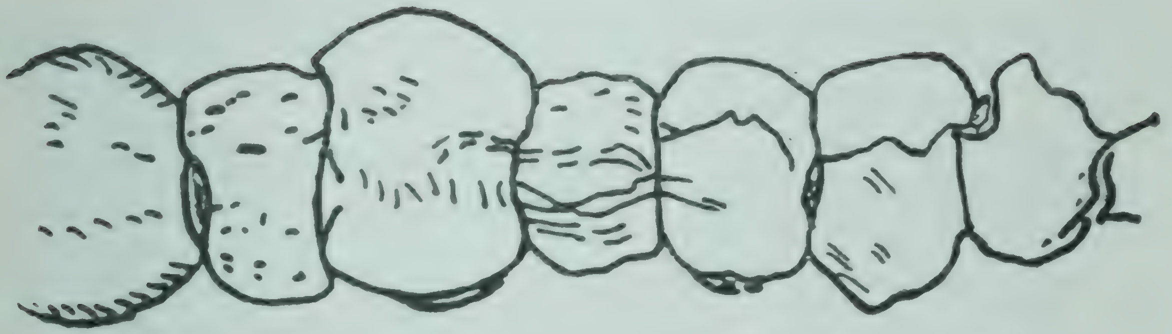


Fig. 6. Cotton Fibre Swollen in Cuprammonium Hydroxide Solution

Striations, observed inside the balloon, are produced by the fibrils which are strands of cellulose deposited spirally along the length of the fibre (Fig. 7). The cross-section of the swollen fibre shows the concentric layers of cellulose or 'growth rings'. These growth rings are formed by the intermittent deposition of cellulose in the fibre, the growth of the plant being arrested during the afternoons and the deposition of cellulose taking place only at night. However, Kerr (1937) suggests that the deposition of cellulose is a continuous process that varies in rate when temperature differences occur, that the fibre wall is a continuous matrix of cellulose and that the laminated or layer-like appearance in swollen sections is due to the alterations of the dense and less dense zones of cellulose. Anderson and Kerr (1938) pointed out that no growth rings were produced when the cotton was grown under artificial conditions of constant illumination and temperature. They also showed that they could control the growth ring pattern and the thickness of the growth rings by varying the temperature and the amount of light under which the cotton plants grew.

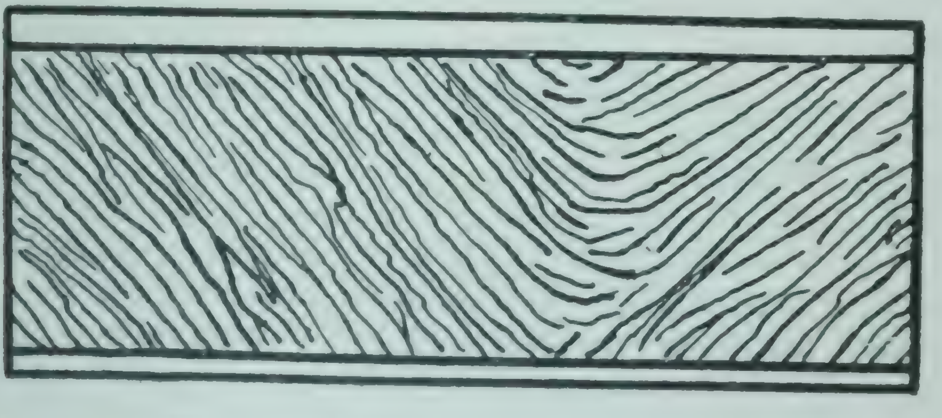


Fig. 7. Spiral Cellulose Strands in Secondary Wall

It was stated that the secondary wall is made up of fibrils in different layers. The outermost layer of the scondary wall, i.e., the layer just beneath the primary wall, appears to be different from the subsequent layers. Anderson and Kerr (1938) found this layer to be made up of coarse fibrils, and it has been called the 'winding'. The fibrils in this layer appear to be closely spaced and form a spiral with both left hand and right hand twists, the direction of the twist reversing in many places along the length of the fibre. The next layer of secondary thickening consists of finer fibrils spiralling in the same helical form along the length of the fibre, reversing its direction at frequent intervals. But the orientation of these fibrils is opposite or almost perpendicular to that of the fibrils in the winding layer. All the other layers of secondary thickening are presumably similar to this layer, except the innermost one which is immediately adjacent to the lumen and is supposed to be similar in structure and behaviour to the winding layer (Fig. 8). The places, where the fibrillar direction of different layers of the secondary wall changes, generally coincide. The fibrils in the central region, excluding the outermost and the innermost layers, are more nearly parallel, and are orientated at an angle of 25° to 35° to the fibre axis. The average diameter of the fibrils is 100 Å to 200 Å.

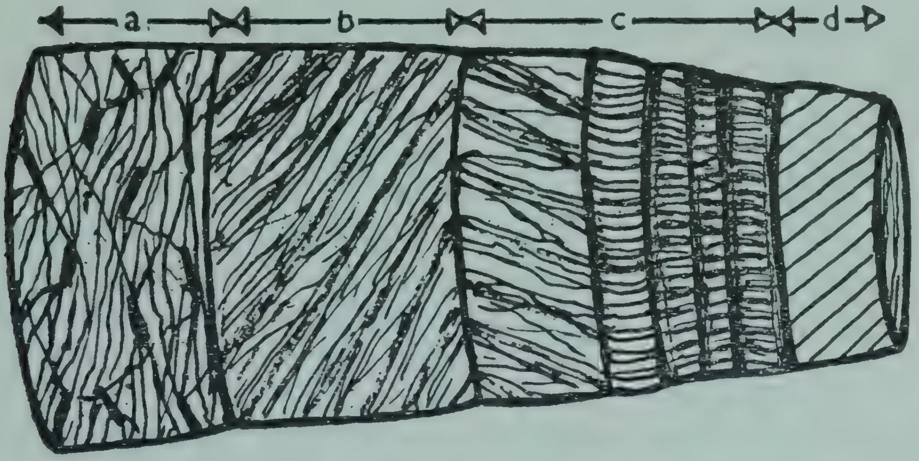


Fig. 8. Longitudinal Section of Cotton Fibre Showing Net-like Structure in Primary Wall (a), and Net and Fibril Structure in the First Layer (b) and Fibrils in the Central Layers (c) and Inner Layers (d) of Secondary Wall

The nature of the primary wall and the orientation of fibrils in the secondary wall are two structural characteristics of the cotton fibre, which play an important part in its swelling behaviour. As the fibrils in the secondary wall are orientated more or less in the direction of the fibre axis, the fibres swell more in the transverse direction than in the lengthwise direction, when the fibre is placed in a swelling medium. Consequently, this transverse swelling of the cellulose in the secondary wall often ruptures the primary wall at some places; under the swelling pressure, the ruptured portions of the primary wall roll back and form rings, which restrict the uniform swelling of the fibre. Even when the primary wall is removed, irregular swelling of the secondary wall persists, which is said to be due to the similar behaviour of the winding layer.

The presence of fibrillar reversals and the absence of any criss-cross network of cellulose are special features of the secondary wall. A fibre reversal occurs at those points, where the direction of rotation of the cellulose fibrils along the fibre axis changes from a Z direction to a S direction and *vice versa*. As mentioned earlier, the cotton fibre grows inside a boll, due to the limited space available, in a zigzag pattern by folding back and forth many times (Fig. 2). Since the secondary deposition takes place in the bent condition of the fibre, it is thought that the reversals of the fibrils coincide with these bends. These places are weaker due to the internal stresses and strains produced during the growth of the fibre and, therefore, cotton fibres tend to break preferentially at the structural reversals. The reversals can be readily located in the natural unswollen fibre by observing it under a microscope using elliptically polarised light; since the interference colours of the Z and S rotations are complementary, the places at which the colour changes indicate the reversals. They are spaced at random along the length of a cotton fibre approximately 100 to an inch.

The spiral pattern of the fibrillar structure causes the natural twists or convolutions when the fibre dries and collapses. The changes in the direction of convolutions along the length of the fibre coincide with the reversals of the fibrils in the secondary wall. The convolutions are supposed to be due to the shrinkage, which accompanies the process of drying, between the molecules, crystallites and fibrils, thus creating tension diagonal to the long axis of the fibre. To some extent, the tension is released by the twisting of the fibre. According to Urquhart (1929), the original deposit of cellulose in the fibre is made in the presence of water. On the loss of water, there will be a tendency for the cellulose units to re-orientate themselves so that the residual balances of the hydroxyl groups may become mutually satisfied. There may be an actual deformation produced for the micelles in an effort to bring free hydroxyl groups nearer each other, which may explain the formation of convolutions in desiccated fibres.

Lumen. Lumen is the central canal or tubular space bounded by the secondary wall. Its contour is more regular in the living fibre cell than when it is desiccated. The irregularity in the width of the lumen is due to the variation in the thickness of the secondary wall as a result of unequal deposition of cellulose. Electron microscopic studies have revealed that the lumen has a spongy granular structure without any fibrils and contains the protoplasmic residue which is mostly proteinaceous in nature.

MOLECULAR STRUCTURE

Ninety per cent. of the cotton fibre is made up of cellulose, the remaining being moisture, waxes, pectic substances and inorganic matter. The chemical properties of the cellulose determine the usefulness of cotton and the conditions to which cotton goods may safely be exposed without undergoing excessive deterioration. The chemical nature of the cellulose assumes, therefore, great importance.

The cellulose molecule is a long chain molecule, consisting of a large number of glucose residues linked together lengthwise end to end by an oxygen linkage, and by secondary valencies, such as hydrogen bonding, laterally. It contains three hydroxyl groups for every glucose residue, and terminates at one end in an extra hydroxyl group and at the other in an aldehydic group which has reducing properties (Fig. 9). The average number of these repeating units in the chain molecule is called the chain-length or degree of polymerisation (D.P.); the D.P. of cotton cellulose is of the order of 3,000 corresponding to a molecular weight of about 500,000.

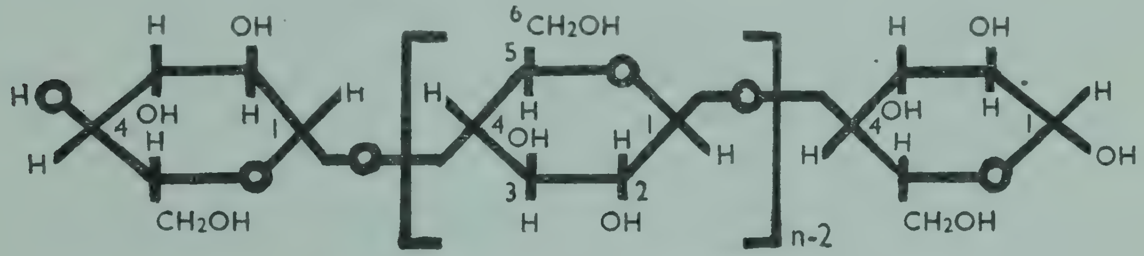


Fig. 9. Cellulose Chain Molecule

The chemical degradation of cellulose (hydrolysis by acids) can result in the breaking of the long chain molecules into shorter ones. It has been found generally that cellulose fibres, which have longer chain molecules, give greater fibre strength. This accounts for the robust and durable nature of cotton as compared to viscose in which the chain molecules are shorter.

It is the hydroxyl or alcoholic groups which determine largely the chemical behaviour of cotton. The typical reactions of alcoholic groups, viz., esterification, etherification, oxidation to aldehydes and carboxylic acids, ionisation under specific conditions, hydrogen bonding, etc., are all shown by cotton fibres, and these reactions bring about many chemical changes having important commercial applications.

FINE STRUCTURE

The cellulose molecules are not independent of each other, but loosely joined end to end and also laterally by forces which are at present only imperfectly understood. Again, these long-chain molecules are packed together inside the cotton fibre in a particular manner, on which depend many of its physical and chemical properties.

It is well-known that a crystal behaves as a three dimensional diffraction grating to the radiation of X-rays, indicating the regularity of inter-atomic distances and, hence, of internal structure. When a beam of X-rays passes through a bundle of parallel fibres at right angles to the fibre axis, a characteristic diffraction pattern (Plate Ia) is obtained, similar to the one produced by a crystal rotating about a principal axis at right angles to the beam. This suggests the existence in the fibre of a number of crystalline regions with their principal axes in the same direction. In these crystalline regions, the chain molecules are regularly packed in an order and their repeating units recur in as ystematic array in all the three directions. The units, thus, form a three-dimensional pattern, called the crystalline lattice.

In the other regions of the fibre, about which the X-ray examination gives us no direct information, the chain molecules are distributed at random. These regions are called the amorphous regions. The evidence for the existence of amorphous regions is obtained from the chemical behaviour of cotton during swelling, hydrolysis in dilute acids, etc. The crystalline and amorphous portions merge into each other and there is no clear-cut demarcation between the two (Fig. 10).

The average length of the crystalline region has been estimated to be about 600Å, and the width 60Å to 70Å, whereas the average length of the chain molecules, as determined by the viscosity method, etc., works out about ten times this value. This suggests that the same molecule passes through a number of crystalline as well as intervening amorphous regions.

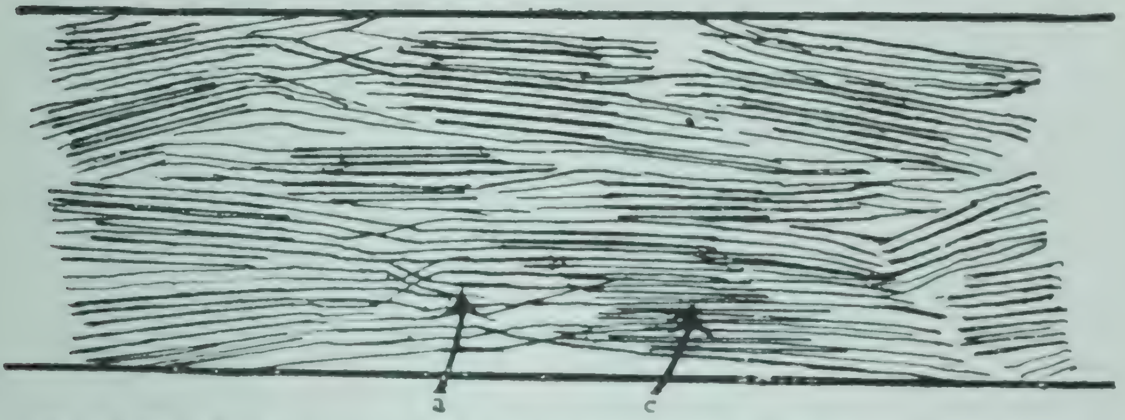


Fig. 10. Two-Phase Structure of Cellulose. **a**. Amorphous Region, c. Crystalline Region

The unit cell in the crystalline region is a parallelepiped (Fig. 11). It appears that the lattice on which the cellulose crystal is built may be ascribed to the monoclinic system, with the dimensions of the unit cell as follows: **a**-axis (horizontal) 8·35Å, **b**-axis (vertical) 10·3Å, and **c**-axis (forming an angle with **a**-axis) 7·9 Å, and β, the angle between **a**-and **c**-axes, 84°. The length of the cell along the **b**-axis is equal to the length of two glucose units or a cellobiose unit. Four cellobiose units form the four corners of the unit cell, all having the same direction. The fifth unit passes through the centre in an opposite direction.

In the crystalline regions, the fibre molecules are attracted to each other laterally by the secondary forces. The strength of the fibre depends, to some extent, on the proportion of its crystalline regions, but high crystallinity makes the fibres more rigid and less pliable.

Most chemical reactions are assumed to take place in the more easily accessible amorphous regions of the fibre, as the reagent molecules find it

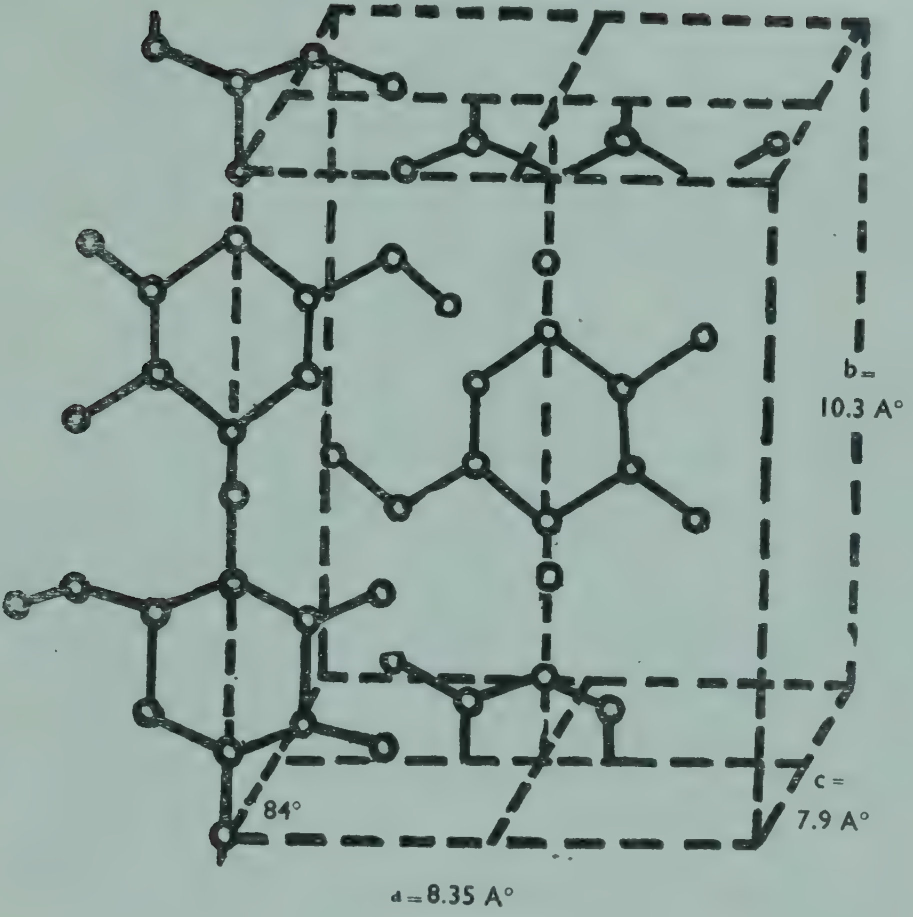


Fig. 11. Unit Cell of Cellulose

difficult to penetrate the crystalline regions. The natural moisture of the fibre is also believed to be held in the amorphous regions only. However, certain physical and chemical treatments change the proportion of crystalline and amorphous regions.

In recent years, various attempts have been made to determine the crystalline-amorphous ratio in the fibre by both chemical and X-ray methods. The crystallinity percentage in cotton has been observed to be between 70 and 90, the wide variation in the values being due to the different methods employed for the estimation of crystallinity.

Considerable attention has been paid, of late, to the crystallite orientation to the fibre axis. This orientation has been determined by measuring the intensity distribution along the 002 diffraction arcs of the X-ray photograph or by measuring the 40 per cent. X-ray angle, which is the angle at which the intensity is 40 per cent. of the maximum. Cotton fibre has a poor orientation as compared with other natural cellulose fibres. Sisson (1938) attributed this to the spiral arrangement of the fibrils in cotton. According to Morey (1934), the average angles of spiral for some of the fibres are as follows: hemp 0°, ramie 3·5°, flax 5·5°, and cotton 45° to 50°.

It has been observed by many workers that the strength of the fibre is highly correlated with the degree of orientation of the crystallites.

Another modern technique in the X-ray examination of fibres has been the study of scattered radiation at very small angles adjacent to the primary beam, from which the size, shape and orientation of the crystallites have been obtained. This method has also been used for distinguishing different types of fibres of the same general composition.

CHEMICAL COMPOSITION OF COTTON FIBRE

A study of the structure of cotton fibre will be incomplete if we do not take into account its chemical composition. For, the properties of the fibre are governed by its structure and chemical composition. The chemical composition of cotton fibre reflects its cellular nature. Most of the substances found in plant cells are present in the fibre, though in very small proportions. The raw fibre consists mainly of cellulose. In addition, it contains small quantities of proteins, pectins, waxes, mineral matter and pigments. Table 2 gives the various constituents of raw cotton on a moisture-free basis.

TABLE 2. COMPOSITION OF TYPICAL MATURE COTTON FIBRES

Constituent	Dry basis*		
	Typical	Low (Percentage)	High
Cellulose	94·0	88·0	96·0
Protein (N x 6·25)	1·3	1·1	1·9
Pectic substances	0·9	0·7	1·2
Ash	1·2	0·7	1·6
Wax	0·6	0·3	1·0
Malic, citric and other organic acids	0·8	0·5	1·0
Total sugars	0·3	—	—
Others	0·9	—	—

* Moisture about 8 per cent. regain.

The variation in the percentage of the constituents is due to variation in the environmental conditions under which the cotton plant grows, and the variety of cotton. Low cellulose content usually indicates a greater proportion of immature or thin-walled fibres. The scoured and bleached cotton is almost 99 per cent. cellulose. The nitrogen is mainly associated with the protein in the lumen and is found to vary with variety. It appears to increase with the increase in the fineness of the fibre. A mild alkali boil readily removes it from cotton fibre.

The pectic substances are mostly confined to the primary wall of the fibre, where their presence may be demonstrated by staining the fibre with ruthenium red. They are readily removed from cotton by a mild [18] alkali boil. The pectins decrease in proportion with age and fineness of the fibre, and the pectic content of a cotton is highly correlated with its surface area per unit weight.

The ash content of the fibre is due to the presence of mineral matter containing chiefly sodium, potassium, calcium and magnesium. These alkali metals occur in combination with pectates and fatty acids. The ash is strongly alkaline, a property typical of the plant ash. About 85 per cent. of the ash is removed from the fibre by extraction with water. Ash alkalinity appears to increase with the fineness of the fibre.

Wax is mostly present as a thin layer on the surface and, therefore, prevents the fibre from absorbing water readily. The cotton wax contains chiefly alcohols and may be extracted with chloroform, benzene or other organic solvents. It acts as a lubricant during the spinning process and gives cohesion to the fibres. The amount of wax in a known weight of cotton has a high correlation with the surface area of the fibres contained in it and does not contribute to the feel of a cotton.

Cotton is a hygroscopic material and absorbs moisture from the atmosphere. The moisture content of cotton is usually expressed as the 'moisture regain', which is the ratio of the weight of moisture contained to the bone dry weight of the material. For commercial purposes, 8·5 per cent. has been agreed upon as a standard regain at 65 per cent. relative humidity and 70° F. temperature.

FIBRE PROPERTIES AND THEIR TECHNOLOGICAL IMPORTANCE

PHYSICAL PROPERTIES

Since fabric quality is mostly governed by that of the yarn from which it is woven, and since the quality of the yarn in turn depends upon the properties of the fibres from which it is spun, the quality of raw cotton is an important factor, which is generally judged from the physical characteristics of the fibre.

Cotton possesses many qualities to make it a good textile fibre. Its dominant position as a textile raw material is primarily due to its versatility for a wide range of end-uses it can be put to. A characteristic feature of cotton, however, is the wide variation in most of its properties, not only between the fibres that constitute a sample, but within a fibre itself.

Fibre Length and Its Distribution. One of the most important and obvious characters of cotton is its length. The staple length of cotton is highly associated with the strength and fineness of the yarn that can be spun from it, and also with its appearance. The world's cottons vary in mean fibre length from about 1/2 inch to 2-1/2 inches, the same cotton having fibres varying in length from 1/8 inch to 3 inches depending upon the variety. Differences in fibre length are, sometimes, responsible for the variation in the spinning performance and yarn quality. The importance of fibre length is due to two factors: firstly, it is length that determines the adjustment and the detailed construction of the machinery for processing; secondly, it determines the amount by which fibres overlap one another in the yarn. The greater the overlap, the easier it is to bind the fibres together by twist, and hence the longer fibres make it possible to spin either stronger or alternatively finer yarns. The longer fibres require less twist to increase the resistance to fibre slippage during the yarn rupture and to produce yarns of greater strength and lustre. Fibre length also affects the incidence of end-slips in the fracture zone, when the yarn is subjected to tension.

The importance of the uniformity of staple has also long been recognised. Irregularity of staple length is considered to be one of the main characteristics of cotton. Although both long and short fibres contribute to the staple irregularity of cotton, it is the short fibres that are responsible for increasing its waste losses and for causing trouble during processing. Further, during the drafting processes, these short fibres will not be under the control of either pair of the rollers. As a result, they produce unevenness of the yarn, which is mainly responsible for its irregularity and weakness, and for the large number of breakages in spinning, winding and weaving. Also, their free ends, by protruding in all directions, give a fuzzy appearnce to the yarn. Finally, the spinning capacity of cotton is more adversely affected by the short fibres than the long fibres.

Fibre Fineness. Another important quality of the fibre which, together with length, accounts for most of the spinning value of cotton is its fineness. Weight per unit length of the fibre is generally taken as a measure of fineness; it is closely related to fibre maturity, because it depends upon both the perimeter (or diameter) and the wall-thickness of the fibre. Fibre diameter is a most stable character of a variety, which generally varies from 12 to 25 microns for different cottons of the world, and is related to the diameter which the fibre had inside the boll, or the original cell diameter. The surface area of the fibres contained in a known weight of cotton is closely related to the weight per unit length of the fibre. It can be measured rapidly and used as a measure of fineness.

When cottons of similar fineness are mixed, the blend shows better processing characteristics. The most obvious influence of fibre fineness on textile properties is, however, its effect on yarn quality and fabric quality, such as drape, handle, ease of creasing, etc.

Fibre Strength. Although it seems obvious that the strength of a yarn must ultimately depend upon the average strength of fibres that compose it, it is observed that only 30 to 50 per cent. of the fibre strength is realised in the yarn strength, depending upon the twist inserted in the yarn. This poor relationship between the single fibre strength and yarn strength is probably because the single fibre strength, as determined in practice, is the strength of the weakest portion of the fibre, and is influenced by its structural features. This position is slightly improved if the ratio of the fibre strength to fibre weight per unit length, which takes into account the number of fibres contained in the yarn, is correlated to the yarn strength.

The variability of single fibre strength is very great, the range being 2.5 to 13 grams for different cottons. The tensile strength of fibre varies from 50,000 to 125,000 lb. per square inch. The long and fine cottons tend to have greater tensile strength than the short and coarse cottons.

The bundle strength of cotton, i.e., the strength of a group of fibres taken together, has been found to give a better correlation to yarn strength. This is probably because the yarn is a bundle of fibres in which the strong and weak points of the fibres are distributed at random and these conditions are, to some extent, simulated in the bundle strength test.

The breaking strength of a fibre depends upon its area of cross-section, test length, type of testing instrument used, the rate of loading, etc.; it also depends upon the relative humidity of the atmosphere. With an increase in relative humidity, the fibre absorbs more moisture with a consequent increase in fibre strength, and the wet strength of the fibre is about 20 per cent. greater than its dry strength. This property of cotton, viz., increase in strength in the wet state, confers a definite advantage, particularly in the washing and wet processing treatments.

Fibre Maturity . Maturity of a cotton fibre indicates the degree of thickening of the cell wall in relation to its diameter. The deposition of cellulose inside the fibre is not uniform in all fibres, and varies widely in fibres on the same seed and even at different portions of a fibre. Fibres having thick cell walls and comparatively a narrow lumen are termed mature, while those having practically no secondary thickening or extremely thin walls and a wide lumen are called immature fibres; those lying intermediate between these two classes, are called half mature fibres (Fig. 12).

Immature or dead fibres are responsible for a number of difficulties which creep in at different stages of processing. They, being weak, are apt to break during the processing of cotton, and thus increase the waste losses; further, they have a tendency to be rolled up into neps specially in the opening and carding processes. Besides causing neppiness, immaturity increases the scouring loss of cotton. The immature fibres possess less capacity for absorbing dyes and thus cause irregular effects in dyeing and printing. Good maturity is closely associated with high fibre weight per unit length and fibre strength. Generally, in medium and long staple cottons, a high fibre maturity gives a better spinning performance.

Convolutions . As explained elsewhere, convolutions are a characteristic feature of cotton fibres. It was believed that the number of convolutions per unit length exerted considerable influence on the spinning properties of a cotton, but recent investigations have not confirmed it. The uniform distribution of the convolutions helps to give better inter-fibre grippage.

It is commonly believed that convolutions confer the following additional

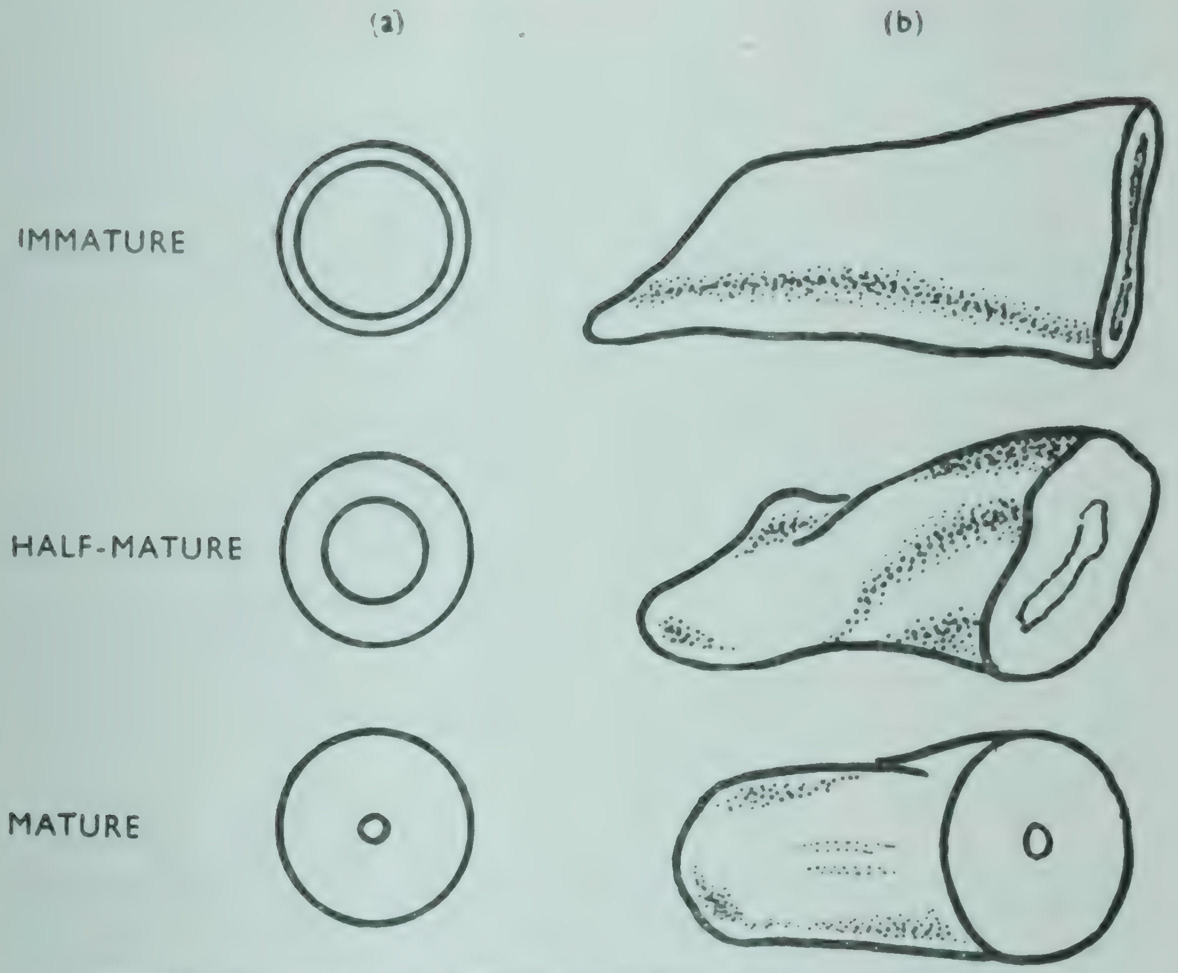


Fig. 12. (a) Cross-Sections of Fibres Before Drying, (b) Longitudinal Views After Drying

advantages: (*i*) they make the fibre equally flexible in all directions; (*ii*) they prevent close packing of fibres in yarn, and hence give better cover in cloth; (*iii*) as they allow only a fraction of the surface of the fibre to be in close contact with its neighbours, they assist good drafting; and (*iv*) as the frictional contact of adjacent fibres is reduced, it lessens the risk of electrification, if any.

The number of convolutions depends, to some extent, on the ratio of cell wall-thickness to ribbon width. Very thin-walled fibres do not convolute until swollen in alkali; similarly very thick-walled fibres convolute little since they do not collapse.

There are fewer convolutions in *herbaceum* and *arboreum* cotton fibres than in *hirsutum* and *barbadense* varieties. The number of convolutions per inch varies from about 150 for Indian cottons to about 300 for Sea Island cotton.

Surface Friction or Clinging Power. The spinning quality of a textile fibre depends not only on its staple length and fineness, but also on its ability to offer sufficient frictional resistance. The effectiveness of friction depends upon the nature of the fibre surface and normal pressure between fibres due to twist. During the drafting processes in the speed frames, the fibres in the roving are pulled out by front rollers, and the movements of these fibres are, to some extent, resisted by their neighbours; this resistance depending upon the frictional force between cotton fibres. Fibre friction plays, thus, an important part in the processing of fibres.

Hygroscopicity. Cotton absorbs moisture from the surrounding atmosphere, depending on its temperature and relative humidity. Moisture has a marked effect on the tensile strength, elasticity and other properties of the fibre. A certain amount of moisture is essential for the efficient processing of cotton. A more detailed account of the moisture relations of cotton is given later.

Rigidity. In processing cotton, the fibres have to be twisted to make a yarn; the more rigid a fibre is, the greater is the force required to twist it and *vice versa*. Thus, fibre rigidity influences the processing of the fibres. Modulus of rigidity is defined as the ratio of the tangential force per unit area to the angle of twist produced. It has been shown to depend upon the shape of cross-section and the wall-thickness of the fibre. It is for this reason that a short staple, coarse cotton, which has thick-walled fibres, requires greater twist to make a yarn of the same size than a long, fine cotton.

Temperature and relative humidity have a great influence on fibre rigidity. At room temperature, the rigidity of the cotton fibre is six times that in an atmosphere saturated with moisture. At constant moisture regain, rigidity decreases as temperature rises. Peirce (1923) found that the mean rigidity of cottons ranges from 0·01 to 0·111 dynes per square centimetre.

Plasticity. Cotton is relatively non-plastic, i.e., it does not deform completely under stresses, but is capable of acquiring semi-permanent plasticity to a considerable extent under certain conditions of humidity, heat and pressure. This property of cotton plays a prominent part in its textile utilisation. Finishing processes like schreinering depend on the increase in the plasticity of cotton fibres as they swell in water at elevated temperatures. The setting of yarn twist results from a plastic decay of elastic couples generated in the fibres by the twist.

Lustre. The natural lustre of cotton fibres seems to be determined by two factors, namely, fibre shape and surface smoothness. It does not appear to depend upon properties like length, fibre weight per unit length, diameter, and convolutions; rather it depends upon the circularity of fibre cross-section. The greater lustre of mercerised fibres is attributed to their comparatively circular cross-section.

Elasticity. It has not been possible so far to measure the elasticity of cotton fibres accurately. The elastic properties of matter are generally expressed in terms of a stress, the force per unit area tending to produce a deformation, and of a strain, the resulting deformation. Changes in length and volume as well as shears or twists produced by applied stresses are all included in the elastic properties. When fibres are elongated under a stress, some of this elongation is recoverable immediately after the stress is removed, some after a long time, and some remains permanently; these three stages are, respectively, called 'immediate elastic recovery' corresponding to perfect elasticity, 'delayed elastic recovery' or 'primary creep', and 'permanent set' or 'secondary creep' corresponding to plastic flow. Cotton fibres are fairly elastic, though they exhibit both the primary creep and the secondary creep to some degree. The elastic limit, i.e., the greatest stress to which the fibre can be subjected without the occurrence of permanent set, has a considerable influence on the extensibility of materials made out of the fibres, and also on the 'set' of fibrous materials.

Elongation is the deformation in the direction of load caused by a tensile force and is expressed in percentage of the original length of the fibre. The amount of elongation before actual rupture of the fibre is a safety factor of considerable practical importance. The extension of cotton fibre at rupture is about seven per cent. under ordinary conditions of temperature and humidity.

Optical Properties. The principal optical properties of the cotton fibre are: (*i*) anisotropy or double refraction; (*ii*) dichroism; and (*iii*) polarised fluorescence.

Anisotropy: The double refraction of the fibre is due to its ordered structure and the orientation of its molecules. This will occur, according to Hermans (1946), equally in the amorphous or the crystalline areas, at a single chain, or even at a glucose molecule. Experiments with plane polarised light have shown that cotton has one refractive index for light vibrating along the optical axis of the fibre and a lower value for light vibrating at right angles to the optical axis. The difference between these two refractive indices is known as birefringence. A study of birefringence of the fibre helps in a better understanding of its structure and molecular orientation, and the changes that take place during the physical and chemical processes, since changes in fibre structure accompanying chemical treatments like mercerisation, etc., are in many cases accompanied by changes in refractive indices. Birefringence studies have thrown interesting light on the moisture relations and stretching of fibres. The Gladstone and Dale's Law for the refractive indices of homogeneous mixtures has been shown to hold good in the case of cellulose-water system up to 20 per cent. regain.

Meredith (1946) correlated the specific strength of fibres with birefringence and obtained a correlation of 0 90. He also observed that the long and fine cottons show greater birefringence and lower spiral angle than the short and coarse cottons, and suggested that the original unconvoluted fibres of all varieties might have the same spiral angle.

Dichroism: It has been known for some time that cotton fibres dyed with direct dyes exhibit dichroism, i.e., they appear differently under polarised light when the plane of polarisation is rotated and the fibres look most deeply coloured when the plane of the electric vector is parallel to the fibres. Fibres with different degrees of molecular orientation show dichroic effects to different degrees and hence, an examination of dyed fibres with polarised light gives a quick indication of the orientation of the fibres.

Fluorescence: Cotton fibres, like other forms of cellulose, fluoresce when irradiated by ultra-violet light. This property has been made use of in distinguishing different grades of cotton, and identifying many defects in the fibre, as well as the oil spots and stains. The use of ultra-violet light for detecting microbial damage has been known for many years and has been suggested for detecting mildew damage in cotton.

Other Properties. Cotton is highly resistant to degradation by heat and can be ironed at high temperatures. The electrical conductivity of cotton appears to vary with relative humidity, and the electrostatic charges influence fibre behaviour during processing.

Among the chief defects of cotton, however, are its tendency to crease and its susceptibility to micro-organisms, but these defects are largely outweighed by its durability, flexibility and washability.

CHEMICAL PROPERTIES

When cotton is heated at 100° C., it loses some of its tensile strength, but it absorbs moisture from the atmosphere on cooling and regains the strength. Prolonged heating at 100°C. causes browning and gradual destruction of the fibre. When heated for short periods at 100°C., the fibre becomes slightly plastic and tends to retain any shape into which it is pressed; this property is made use of in hot finishing operations, such as calendering, schrienering, stretching, etc. Cotton may be boiled in water at 100° C. for long periods without impairing its substance or strength, but as the temperature is raised above 100°C.—when boiled under pressure—a reduction in tensile strength is noticed, and above 200°C. rapid degradation occurs.

Cellulose is readily decomposed in strong acids, but dilute solutions have little effect. Boiling in dilute solutions of mineral acids causes hydrolysis of the oxygen linkage, and tendering occurs; if weak solutions of mineral acid are allowed to dry in cotton, marked tendering takes place. Organic acids are much weaker and have less deleterious effect on cotton. Many salts in aqueous solutions, such as zinc chloride and calcium thiocyanate, have powerful swelling action on cotton and form dispersed solutions. Cotton absorbs metallic salts and tannins, which serve as mordants for certain dyes. Its non-cellulosic impurities, such as proteins, pectins, waxes, etc., are removed by alkaline boiling and bleaching processes, and it is found to be quite resistant to the action of dilute caustic alkalies even at boiling temperature.

Strong solutions of caustic soda, above 10 per cent., have a striking effect on cotton. The fibre begins to untwist and swell, changing in appearance from a twisted ribbon to a round rod; the other effects are shrinkage, increase in strength, increased affinity for dyestuffs and, in general, enhanced chemical reactivity. These changes were first noticed by John Mercer in 1844. The action of strong caustic soda on cotton materials held under tension is the basis of the important finishing operation, viz., mercerisation. Such swelling action is also brought about by strong acids, like sulphuric, nitric and phosphoric acids. The action of sulphuric acid under controlled conditions is utilised in obtaining the organdie finish.

The swelling action is most pronounced in cuprammonium solutions, where the reagent penetrates even into the crystalline regions and the cellulose chains are completely dispersed, forming a viscous solution. The viscosity of such a solution is found to be proportional to the length of the cellulose chains, and, therefore, the fall in viscosity gives a measure of the shortening of the chain length. The degradation of cellulose, brought about by hydrolysis of the oxygen linkage, results in shorter chain length and is indicated by the fall in viscosity and susceptibility of the degraded cellulose to dilute alkali. Oxidation of the cellulose hydroxyl groups to aldehyde groups is indicated by the increased reducing action on silver or copper salts; further oxidation to carboxyl groups results in increased absorption of methylene blue or metallic radicals. However, oxidation is invariably followed by hydrolysis, thereby resulting in the degradation of the cellulose.

COMPARISON BETWEEN PROPERTIES OF COTTON AND OTHER TEXTILE FIBRES

In this connection, it would be interesting to compare some of the physical properties of cotton with those of a few other well-known natural and man-made fibres, the values for which are given in Table 3.

TABLE 3. PHYSICAL PROPERTIES OF SOME NATURAL AND MAN-MADE FIBRES

Properties	Cotton	Silk	Wool	Viscose Rayon	Acetate Rayon	Nylon	Terylene
1. Length	0·5"-2·5"	Filament	1·5"-15·0"	Filament	Filament	Filament	Filament
2. Diameter (0·0001 cm.)	12-25	9-11	10-70	10-43	11-46	11-43	11-28
3. Specific gravity	1·50-1·55	1·25-1·35	1·28-1·33	1·50-1·54	1·30-1·35	1·14	1·38
4. (a) Tensile strength at 65% R.H. (lb./sq. in.)	42,000-125,000	45,000-83,000	17,000-28,000	29,000-78,000	18,000-30,000	65,000-114,000	65,000-104,000
(b) Tenacity (gm./denier) at 65% R.H.	2·1-6·3	2·8-5·2	1·0-1·7	1·5-4·0	1·1-1·8	4·5-7·8	4·5-7·0
(c) Wet strength, % of dry strength at 65% R. H.	110-130	75-95	76-97	44-65	50-75	85-90	100
5. Elongation at break (%) at 65% R. H.	3-10	13-31	20-50	10-30	23-50	15-31	7·5-25
6. Moisture regain (%), at 65% R. H.	8·5	11·0	17·0	11·5-16·6	6·3-6·5	4·7-4·5	0·4
7. Refractive index:							
(a) Parallel to the fibre axis	1·580	1·591	1·556	1·547	1·478	1·547	1·720
(b) Perpendicular to the fibre axis	1·533	1·538	1·547	1·521	1·473	1·521	1·540

It will be seen from these figures that cotton is nearly as strong as, and some cottons even stronger than, nylon, but its elongation at break is about the lowest of the values for all the fibres given in the table. One of the most important characters of immense value is its wet strength, which is about 120 per cent., on an average, of its dry strength, where as the wet strengths of viscose rayon and nylon are about 50 per cent. and 90 per cent., respectively, of their dry strengths.

INTER-RELATIONSHIP BETWEEN FIBRE PROPERTIES

Considerable work has been done on the inter-relationship between fibre properties in the case of Indian cottons. Some of the main conclusions of these studies are given below :

The weight per unit length of a cotton fibre varies along its length, the middle portion being heavier than the two ends; the tapering end has the least weight per unit length.

In a sample of cotton, the fibre weight per unit length varies with different group lengths; generally, it increases with the decrease of group length in *hirsutum* varieties, while it is fairly uniform for *arboreum*, *herbaceum*, Sea Island and Sakel varieties. The fibre strength, as well as the ribbon width, increases with the decrease of group length. Fibre maturity also varies with group length, but the mode of variation is different in different varieties.

In general, the short staple cottons are highly mature, while the long staple ones have a comparatively low maturity.

The weight per unit length of an immature fibre and that of a half mature fibre have been found to be, on an average, 0.40 to 0.45 and 0.60 to 0.75, respectively, of that of a fully mature fibre. Further, immaturity of the fibre is associated with low fibre strength and less number of convolutions per unit length.

The frictional force between fibres with an equal number of convolutions is higher than that between fibres with an unequal number. It is influenced more by the surface corrugations and spacing of convolutions than by the number of convolutions per unit length. The frictional force is found to increase on dewaxing and decrease on alkali treatment of the fibres. Also, it has been observed that fibres with very low fibre weight per unit length and high immaturity generally possess low fibre friction, that the frictional force is highly correlated to the square root of fibre weight per unit length and with the ratio of mean fibre length to fibre weight per unit length, and that higher the maturity of the fibres, greater is the friction between them.

DEGRADATION OF COTTON

The quality of cotton suffers by degradation due to various types of damage which the fibre may undergo, resulting in its lower spinning performance and the inferior quality of the manufactured product. Degradation of the fibre may be due to: (*i*) micro-organisms; (*ii*) machines; (*iii*) chemicals; and (*iv*) heat. These different types of damage are briefly described below:

Microbial Damage. The degradation caused by the micro-organisms has been studied extensively in the mildewing of fabrics, but relatively less extensively in raw cotton.

The organisms persist during ginning, storage and processing of cotton, and develop rapidly under suitable conditions, especially if the humidity is high ; some of them are capable of causing chemical degradation of the cellulose. Damages due to wet storage occur, if the cotton has not been sufficiently dried prior to storage or if stored under humid conditions. A moisture content of 9 per cent. is generally considered the minimum for the growth of microbes in cotton.

Mechanical Damage. This is caused during the ginning and manufacturing processes and also in mechanical picking. Mechanical damage results in two types of degradation, viz. : (*i*) breaking, bruising or crushing of the entire fibre ; and (*ii*) chemical degradation in which the cellulose chains are broken to a certain extent. The first type of damage is detected by microscopic examination and the second by the measurement of fluidity of cellulose. Both types of damage generally occur together in ginning.

Chemical Degradation. This is usually caused during the bleaching, dyeing and finishing operations. Photo-chemical degradation occurs to a small degree in raw cotton, especially during weathering. Accelarated photo-chemical degradation of cotton cloth and yarn by carbon-arc light has been found to result in a loss of breaking strength and increase in fluidity.

Heat Damage. The question of heat degradation assumes importance in the finishing and laundering of fabrics. It is known that degradation is not appreciable below 100° C., but increases at high temperatures. Heat effects create weak spots along the length of the fibre, and an increase in the number of transverse cracks along the fibre has been observed under the microscope ; there is also a decrease in the degree of polymerization, the number of cellulose chains broken being proportional to the time of exposure. Moisture accelerates heat degradation. In the drying process prior to ginning, over drying may cause considerable heat damage to the raw fibre.

LABORATORY METHODS OF DETERMINING IMPORTANT FIBRE PROPERTIES

The evaluation of fibre properties with modern testing instruments in a laboratory affords the most direct means of comparing the merits of different cottons. It enables the selection of a cotton suitable for manufacturing a specific end-product. A few general considerations apply to most of the tests to be described ; among them are the uses of standard conditions of temperature and humidity for the estimation of physical properties, sampling procedure and the number of specimens to be tested.

ATMOSPHERIC CONDITIONS FOR TESTING

Most of the physical and mechanical properties of the fibre, such as weight, strength and flexibility, vary with its moisture content. Physical tests are, therefore, done on cotton fibres in standard conditions of temperature and humidity. The accepted standard conditions are 65 ± 2 per cent. relative humidity and 70 ± 2°F. temperature.

SAMPLING

With such a variable material as cotton, it is most important that the test sample should be representative of the bulk, otherwise accuracy in the measurement of any property would serve no useful purpose by itself. In sampling raw cotton for tests, great care needs to be exercised. Generally, the material to be tested is divided into 32 or 64 equal parts, and from each part, a small pinch of fibres, weighing approximately 10 milligrams, is taken; these pinches are later drafted and doubled several times, so as to get a uniform sliver. The sampling method of Rigney and Nelson is somewhat more elaborate. A special fibre blender for the laboratory has been devised by Stewart (1945) and with this apparatus, it is claimed, uniform cotton samples can be prepared very quickly. For sampling cotton in a bale, an automatic sampling apparatus has been devised. This is said to provide samples of uniform size and weight, representative of the cotton in the bale when the bale is being made from ginned cotton.

Measurement of Fibre Length and Its Distribution. Fibre length is determined in a number of ways. In some of these mere estimations are made by the 'hand and eye' method, while in others instruments are used to give more reliable and reproducible results.

The most direct method of measuring the mean fibre length of a cotton is to measure the individual length of all the fibres constituting a sample and take the average value. This method is definitely more accurate, but is laborious and time-consuming, and therefore, indirect and quick methods are adopted in the laboratory.

The instruments which are generally used for determining fibre length in this country are : (*i*) Balls Sledge Sorter ; (*ii*) Baer Sorter; (*iii*) A. N. Stapling Apparatus ; and (*iv*) Fibrograph.

The Balls Sorter (Plate Ib) consists essentially of two parts, the draw-box and the sledge sorter. The draw-box is used for preparing a sliver in which the fibres are thoroughly mixed, doubled and parallelised so that any portion of the sliver becomes as representative of the whole material as possible. The sledge sorter is a mechanical contrivance which sorts out the fibres from this sliver in order of their length and deposits them automatically on a black plush provided with a calibrated tape, the shortest fibres being deposited first and the longest at the end. The weight of fibres lying in each 1/8 inch length group is determined, and the ratio of the total sum of the products of the group lengths and their corresponding weights to the total weight of the groups, gives the mean fibre length. The frequency distribution of length by weight is also, thus, obtained. Further, the fibre length irregularity is determined by calculating the percentage by weight of such fibres as are shorter than three-fourths of the mode.

The Baer Sorter consists of a set of parallel combs mounted on a metal frame. The cotton sample, to be tested, is made into a hand sliver and held in the series of combs, and the fibres at one end of the sliver are aligned by means of tweezers. Bunches of fibres are then pulled out with the tweezers and placed gently, one over the other, on the combs at one side of the frame in such a manner that the comb nearest to the operator forms the starting line for the tufts. The frame supporting the combs is turned through 180°, and the longest fibres extending beyond the front comb are pulled out with the tweezers and placed on a piece of plush side by side. When these fibres are exhausted, the front comb is dropped and the protruding fibres, next in order of length, are removed and laid on the plush adjacent to the previous fibres, all the fibres being carefully spread out to uniform density. The process is repeated until no fibres are left on the combs, when a pattern in the form of a fibre array is obtained. The area of the pattern is measured by means of a special celluloid scale with squares marked on it, and the mean length is calculated by dividing the area by the length of the fibre array.

Certain other measures, like the effective length, dispersion percentage and percentage of short fibres, are calculated from a trace of the Baer Sorter pattern on a translucent paper. This stapling technique is employed in the United Kingdom.

The Suter-Webb Sorter, used in the United States, is a slight variation of the Baer Sorter. This instrument consists of two frames, and the fibres, after being placed on one set of combs as in the case of the Baer Sorter, are transferred to the other set by a series of small 'pulls' before they are arranged on the plush. The fibres in the pattern are then raked into groups of 1/16 inch intervals and weighed to the nearest 0.5 milligram, and the mean length is worked out.

The Ahmad-Nanjundayya Stapling Apparatus (Plate IIa) employs the weight ratio method and is based on the finding that a cotton fibre is heavier at its middle portion than at the ends. In this method, a representative tuft of fibres, having their one end aligned, is cut into three portions by means of two razor blades fixed in a cutter, and the extreme portions are weighed in a torsion balance. The length of the first portion from the aligned end is known by previous adjustment, and the mean length of fibres composing the third portion is calculated by assuming that the weight per unit length in these two portions of the tuft is nearly the same. The total of these three lengths (length of the middle portion between the blades is constant) gives the mean length of the cotton. The frequency distribution of length can also be determined with the help of this instrument using a small attachment designed for this purpose.

Recently, a photo-electric instrument called the Fibrograph (Plate IIb) has come into vogue and is being used extensively. It measures the optical density of a combed sample and traces a length frequency curve, called fibrogram. From this diagram, the 'upper half mean length' and the 'mean length' of the cotton are worked out, and the ratio of the mean length to the upper half mean length expressed as a percentage, is taken as the 'uniformity ratio'. This instrument gives the staple length and its uniformity quickly.

Besides the above instruments, there are a few others, among which mention may be made of the Uster Stapling Apparatus and the Shirley Institute's Photo-electric Staple Tester.

Fibre Fineness. The original cell diameter of the fibre is the true measure of its fineness. The diameter of the fibre is measured by a microscope. The swollen fibre diameter, i.e., the diameter of the fibre swollen in 18 per cent. caustic soda, gives a better estimation of the original cell diameter than that of the raw fibre. However, as these tests are laborious and time-consuming, diameter measurements are not usually done for the estimation of fineness.

Fineness of a cotton is, therefore, measured by the gravimetric method by determining the fibre weight per unit length. One of the methods consists in cutting one centimetre lengths of fibres from the middle portion of a small tuft, counting them between two glass slides under a low-power microscope and weighing them on a sensitive quartz micro-balance. But, this method is open to objection in the case of Indian cottons, where it is observed that the weight per unit length varies along the length of the fibre, the middle portion being heavier than the ends. The method followed in this country, therefore, consists in weighing small bunches of whole fibres in a quartz micro-balance. Each bunch contains between 80 and 200 fibres, depending on whether the cotton is coarse or fine, so as to obtain approximately the same deflection as produced by a 0.5 milligram weight. In this way, the necessity of calibrating the balance along the entire length of the scale is dispensed with, and altogether, some 2,000 fibres are weighed in 10 to 25 bunches. The total weight of all the bunches divided by the total number of fibres, gives the weight per fibre of average length. The ratio of this value to the mean fibre length, obtained by any one of the methods described earlier, gives the fibre weight per unit length.

The fibre weight per unit length can also be determined, along with the fibre length, by the Ahmad-Nanjundayya Stapling Apparatus. The fibres in the first portion, after cutting, are counted under the microscope before weighing it. This gives the total number of fibres contained in the tuft. The total weight of the three portions divided by the number of fibres, gives the weight per fibre.

Of late, air-flow instruments are being used extensively for the quick determination of fibre fineness. These instruments are based on the principle that the resistance offered by a known weight of cotton to the flow of air depends on the total surface area of the fibres in that sample, the long and fine fibres, which have a larger surface area per unit weight, offering greater resistance to the air-flow than the short and coarse fibres. Since the surface area per unit weight of the fibre is, in turn, related to its weight per unit length, some of the instruments are calibrated to give the latter directly. Several instruments have been developed on the above principle, of which the Micronaire (Plate III) and the Arealometer are the most common.

In the Micronaire, a definite weight of cotton (50 grains) is placed in the specimen holder and compressed to a constant volume. Air at a constant pressure is forced through the cotton plug, and the resistance offered by the cotton to the flow of air is indicated by the position of a float in the vertical tube attached to the compression chamber. The instrument is calibrated to give fibre fineness in terms of microgrammes per inch. Micronaire readings are influenced by heavy trash, relative humidity above 80 per cent. or below 45 per cent., and damaged fibres. The following ratings, according to fineness, have been suggesed for application in the case of American Upland cottons.

Microgrammes per inch	Rating
Below 3·0	Very Fine
3·0 — 3·9	Fine
4·0 — 4·9	Average
5·0 — 5·9	Coarse
Above 5·9	Very coarse

The Arealometer is designed to measure the ratio of the fibre surface to fibre volume, and this specific surface can be used as a measure of fineness. The other air-flow instruments, which can be used for fibre fineness measurements, are the Air-Permeameter as modified by Rajaraman and Sen, the Speedar and the Port-Ar, the last two being modifications of the Arealometer.

Maturity. The usual method of determining the maturity of cotton is to swell the fibres in a solution of 18 per cent. caustic soda and judge the swollen wall-thickness of each fibre in relation to its lumen. For a regular test, a bunch of fibres drawn from a sliver is taken on a glass slide and a cover slip placed on it. The fibres are next irrigated with the caustic soda solution, and their maturity is determined with the aid of a microscope, preferably a projection microscope. They are classed into three groups., viz., mature, half-mature and immature fibres, which are expressed in percentage. Some workers, especially in the United States, classify the fibres only into two categories, mature and immature.

In an alternate method, the polarising properties of the fibre are employed. About 100 fibres are mounted parallel to each other between two slides and observed under a polarising microscope, having a selenite plate placed between the crossed polariser and analyser with the slow direction at 45° with respect to both, the fibres being kept parallel to the slow vibrations of the selenite plate. A fibre which looks yellow or yellowish green is mature, blue or bluish green, half-mature, and deep blue or purple, immature.

A visual method for distinguishing mature and immature fibres by differential dyeing, developed at the Southern Regional Research Laboratory of the United States Department of Agriculture, employs a mixture of two colours, Diphenyl Fast Red 5 BL and Chlorantine Fast Green BLL, having different dyeing properties. Mature fibres absorb the red dye preferentially and the immature fibres the green one. A sample of cotton dyed with these two dyes in admixture, has red and green patches depending upon the proportions of mature and immature fibres.

Realising the advantages of using a single dye for the determination of maturity, a suitable technique was developed at the Technological Laboratory, Bombay. An acid dye, Carbolan Violet 2 R. S. is used in this test. The immature fibres take up a deeper shade than the mature ones. An estimate of the maturity can be obtained by comparing a dyed sample against shade standards prepared with the help of the caustic soda swelling method.

Another method of determining the maturity is by the use of air-flow instruments. Hertel and Craven (1951) observed that, if the resistance to air-flow through a cotton plug as in the Arealometer is measured under two different pressures, a difference in the specific surfaces is obtained, which is related to maturity, and that the increase in specific surface under high compression was greater for immature cotton than for the mature. This finding has been utilised to work out an index of maturity by using the Arealometer. The Micronaire also can be employed to measure what is called the causticaire maturity, by testing a sample of cotton in the raw state and after mercerising it with caustic soda solution of 40° Tw. The causticaire maturity is given by the relation:

$$\text{Maturity index} = \frac{\text{Causticaire scale reading (untreated)} \times 100}{\text{Causticaire scale reading (treated)}}$$

The fibre weight per unit length of a cotton as a criterion of its fineness is affected by the variation in the maturity of fibres composing the sample. In order to give proper weightage to fibres falling in the three maturity classes, the idea of maturity coefficient was developed. The observed fibre weight per unit length divided by the maturity coefficient gives an expression characteristic of the strain of cotton, independent of maturity, the square root of which is proportional to the original cell diameter of the fibre. The maturity coefficient for Indian cottons is given by the relation:

$$M_C = \frac{M + 0\cdot6\,H + 0\cdot4\,I}{100}$$

where M, H and I represent the percentages of mature, half-mature and immature fibres, respectively, in the sample.

A similar measure employed in the United Kingdom is the maturity ratio, which is defined by the expression, $M = \frac{(N - D)}{200} + 0\cdot70$, where N and D are the percentages of normal and dead fibres, respectively.

Fibre Strength. Fibre strength may be measured either as the strength of a single fibre or as the strength of a bundle of fibres. Although the determination of single fibre strength is tedious, it is very useful for research purposes. In India, single fibre strength testing is usually done by the Balls' Magazine Hair Tester and the modified O'Neill instrument called the Dial Reading Strength Tester.

The Magazine Hair Tester is an automatic instrument, consisting essentially of a compound pendulum, which swings in frictionless cup-and-vee bearings on steel points and is mounted on a carriage, moving forward and backward along an endless screw. The pendulum is attached to a suspended hook which drops into an eyelet. One end of the fibre to be tested is attached to the eyelet, the other end being fixed to a magazine disc which can hold 50 fibres in this way. When the carriage moves away from the magazine disc, the pendulum pulls the fibre by means of the hook and the displacement of the pendulum is recorded by an electric spark between an attached needle and a plate facing it. The plate is covered with a thin tissue paper, on which an arc is traced by the spark, whose length depends on the strength of the fibre. When the fibre snaps, the pendulum swings back to position, the motion of the carriage is reversed and the magazine disc moves round one space bringing another fibre for breaking. The record thus consists of a series of charred arcs on the paper. By the use of a special calibrated scale, the breaking strength is calculated.

The modified O'Neill Strength Tester consists essentially of three parts: (*i*) a 'U' tube in which two floats are suspended in a calcium chloride solution of appropriate density; (*ii*) a device by which a fibre is suspended and which makes an electrical contact when the fibre is straightened out; and (*iii*) a mechanism for lifting one of the floats at a uniform rate and automatically recording the tension applied to the fibre. The fibre is suspended in a hook fixed to the device mentioned above, in which an electric circuit is completed as soon as the fibre becomes taut. The other end of the fibre is attached to the float in one arm of the 'U' tube, while tension is applied to the fibre by raising the second float, which acts as a counterpoise by winding a string on a pulley driven by a small electric motor. The same gear arrangement lifts the float and also records the tension applied to the fibre on two calibrated dials. The mechanism for applying and recording the tension works only so long as the circuit is not cut off. When the fibre snaps, the electric circuit is broken and both the pointers and the counterpoise come to rest. The readings on the dials are then noted, and the breaking strength of the fibre is calculated.

Mention may be made of two other instruments which give strength elongation curves besides the breaking strength, and these are the Cambridge Textile Extensometer and the Instron Tensile Tester.

The Cambridge Textile Extensometer is a versatile instrument and can be used either as a constant rate of loading or a constant rate of extension instrument. The load extension curves for the fibres can be recorded under increasing or decreasing load, and the specimen under test can lie immersed in a liquid, the temperature of which may be controlled, if desired.

The Instron Tensile Tester measures the load-elongation properties of textile fibres at a constant rate of elongation. It has an electronic loading system which covers a range from 10 grams to about 450 kilograms. This instrument records even small load fluctuations in the sample. Due to the absence of mechanical friction, it is capable of a high degree of accuracy.

As the yarn consists of a bunch of fibres twisted together, the bundle strength of fibres would obviously have a better relation to yarn strength than the single fibre strength, besides being quicker to test. The measurement of bundle strength has, therefore, now become a common practice. The Chandler Bundle Strength Tester was being used in the United States for the determination of the bundle strength of cotton fibres. But it has been replaced by the Pressley Flat Bundle Strength Tester. This instrument has become very popular and is now used all over the world.

The Pressley Strength Tester is an inclined plane instrument in which a heavy load moving along the inclined plane exerts the force necessary to break a tuft of fibres. A flat fibre bundle of suitable size is fixed between a pair of clamps with sufficient pressure to avoid fibre slippage. The protruding fibres are removed by a sharp edge, so that a tuft of constant length is held between the clamps, which are then inserted in the jaws of the instrument. The heavy weight is released when it goes on sliding along the beam and stops as soon as the tuft is broken, and the position of the weight on the beam gives the load required to break the tuft. Next, the two portions of the broken fibre bundle are collected and weighed. The ratio of the breaking strength of the tuft to its weight gives the Pressley Index. This index can be converted to pounds per square inch by the following relationship:

Estimated 1,000 pounds per square inch = (10.8116 × Pressley Index) − 0.12.

The United States Department of Agriculture suggests the following grades for rating cottons according to strength (see table on the next page).

The Pressley Strength Tester can be used at zero or 1/8 inch gauge length between clamps and, therefore, it is necessary to mention the gauge length when the latter is used. It has, however, been observed that the bundle

Strength in 1000 lb. per sq. inch	Rating
Above 95	Very Strong
86-95	Strong
76-85	Average
66-75	Fair
Below 66	Weak

strength of a cotton at 1/8 inch gauge length has a better correlation with yarn strength than that at zero gauge. Two other instruments, viz., the Clemson Flat Bundle Strength Tester and the Stelometer (Plate IV) have been recently developed in the United States, in which variable gauge lengths could be employed, and the latter gives the elongation of the fibre bundle also.

The Scott's constant rate of loading machine has been used for the determination of bundle strength of cotton fibres, of late, by some research workers. In this instrument, clamps similar to those of the Pressley Strength Tester are employed. This is claimed to give more reliable estimates of fibre strength.

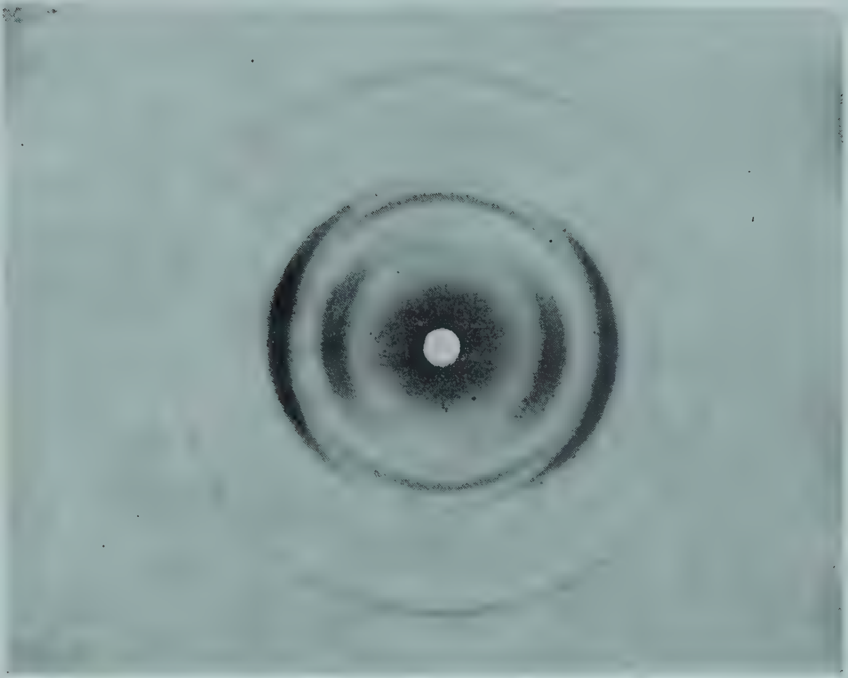
Lastly, in this connection, the humidity correction tables for the determination of the fibre weight by the counting and weighing method, and the single fibre strength, being used at the Technological Laboratory, are given in Tables 4 and 5.

TABLE 4. HUMIDITY CORRECTION (FIBRE WEIGHT)

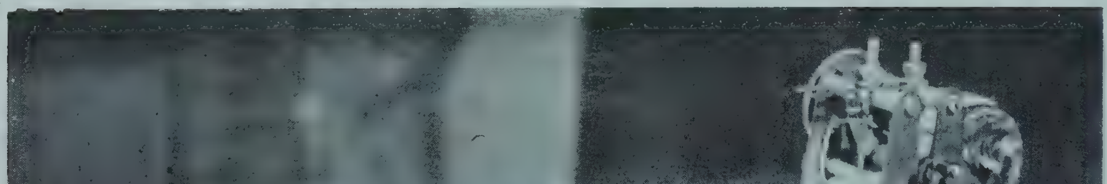
	20	30	40	50	60	70	80
0	—	4·1	3·1	2·0	0·7	—0·7	—2·5
1	—	4·0	2·9	1·8	0·5	—0·8	—2·8
2	—	3·9	2·8	1·7	0·4	—1·0	—3·1
3	—	3·8	2·7	1·6	0·3	—1·1	—3·4
4	—	3·7	2·6	1·5	0·2	—1·3	—3·7
5	4·5	3·6	2·5	1·3	0·0	—1·5	—3·9
6	4·4	3·5	2·4	1·2	—0·1	—1·7	—4·2
7	4·4	3·4	2·3	1·1	—0·3	—1·9	—4·6
8	4·3	3·3	2·2	1·0	—0·4	—2·1	—5·0
9	4·2	3·2	2·1	0·8	—0·5	—2·3	—5·4

By using the formula, $W_{65}=W_h\left(1+\frac{K_h}{100}\right)$, where W_{65} and W_h are the fibre weights at 65 per cent. relative humidity and h per cent. relative humidity, respectively, and K_h is the correction factor given in Table 4, the fibre weight at 65 per cent. relative humidity is calculated from the value at any humidity.

Similarly, the formula, $S_{65} = S_h \times C$, where S_{65} and S_h are the single fibre strengths at 65 per cent. relative humidity and h per cent. relative humidity, respectively, and C_h the correction factor given in Table 5, is used to reduce fibre strength at any humidity to that at 65 per cent. relative humidity.

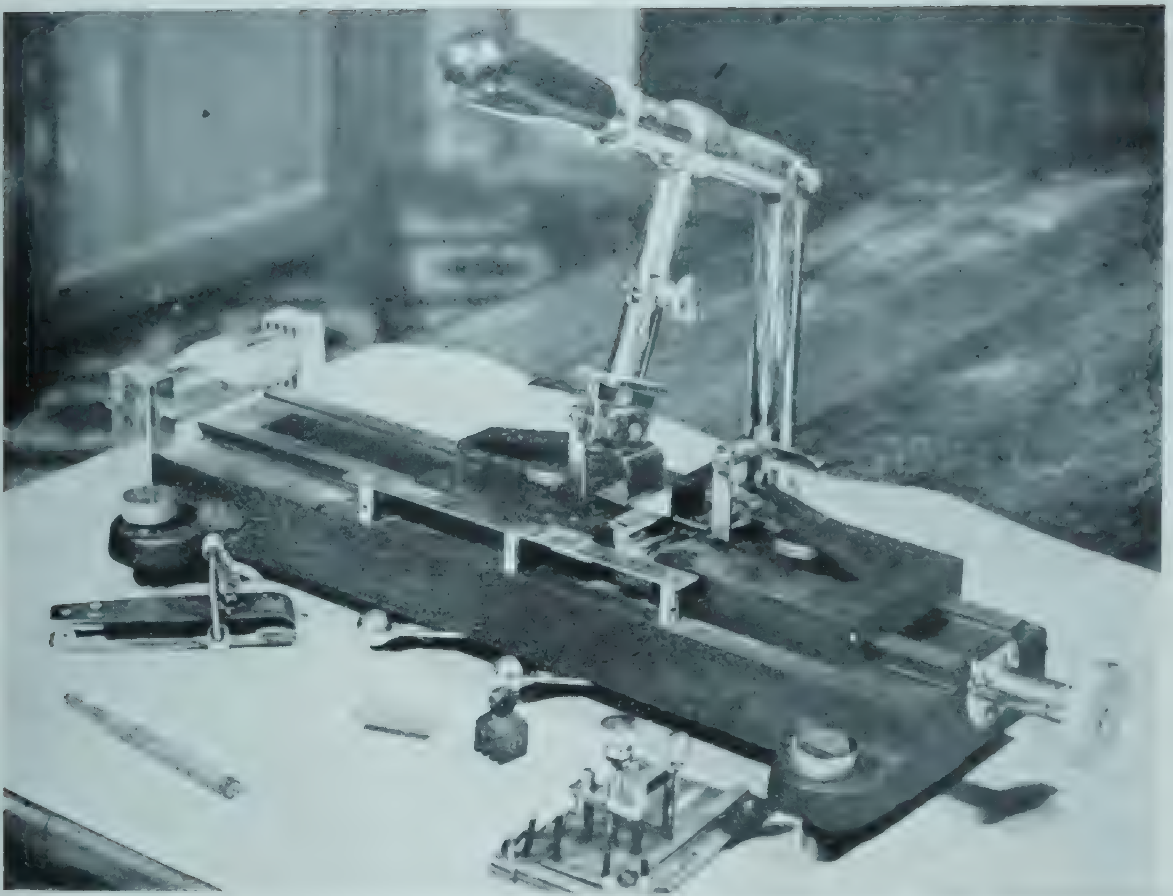


a. X-Ray Diagram of Cotton Fibre

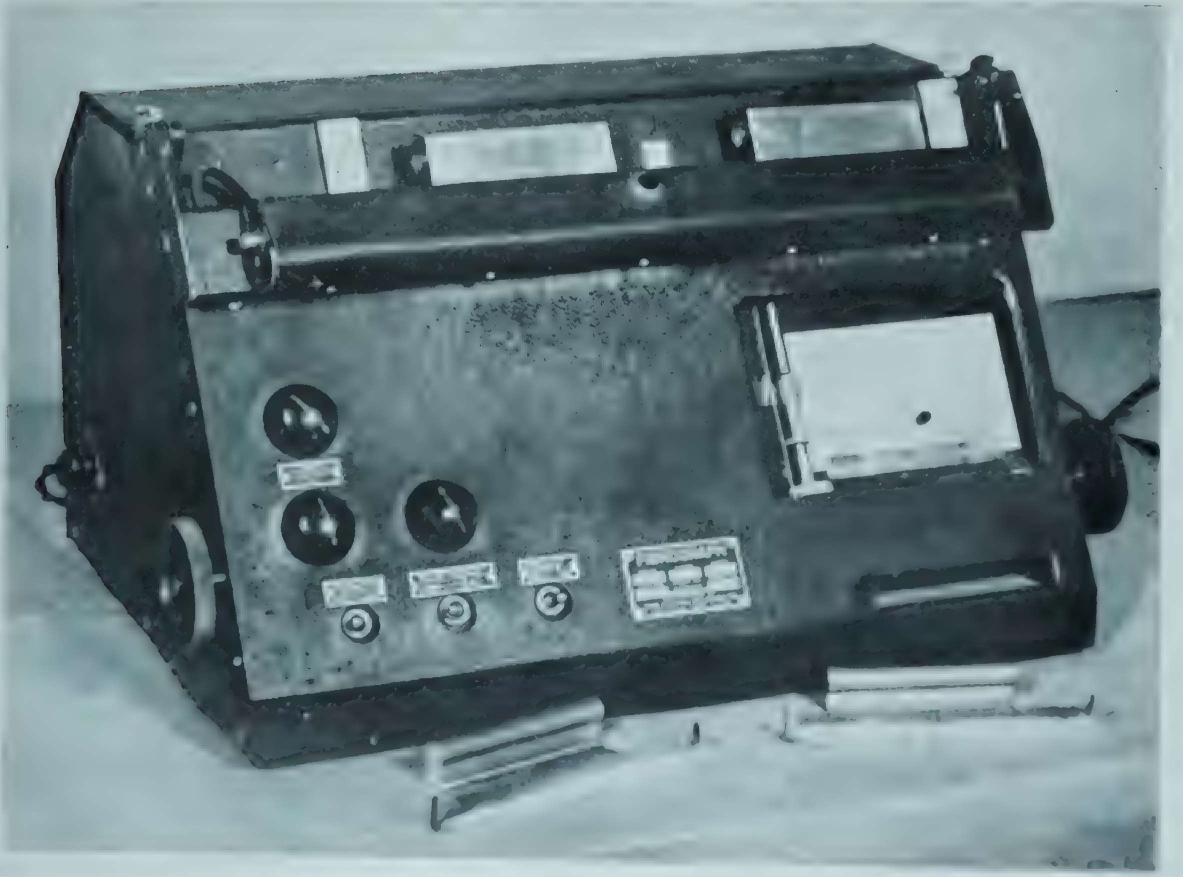


b. Balls Sorter

PLATE II

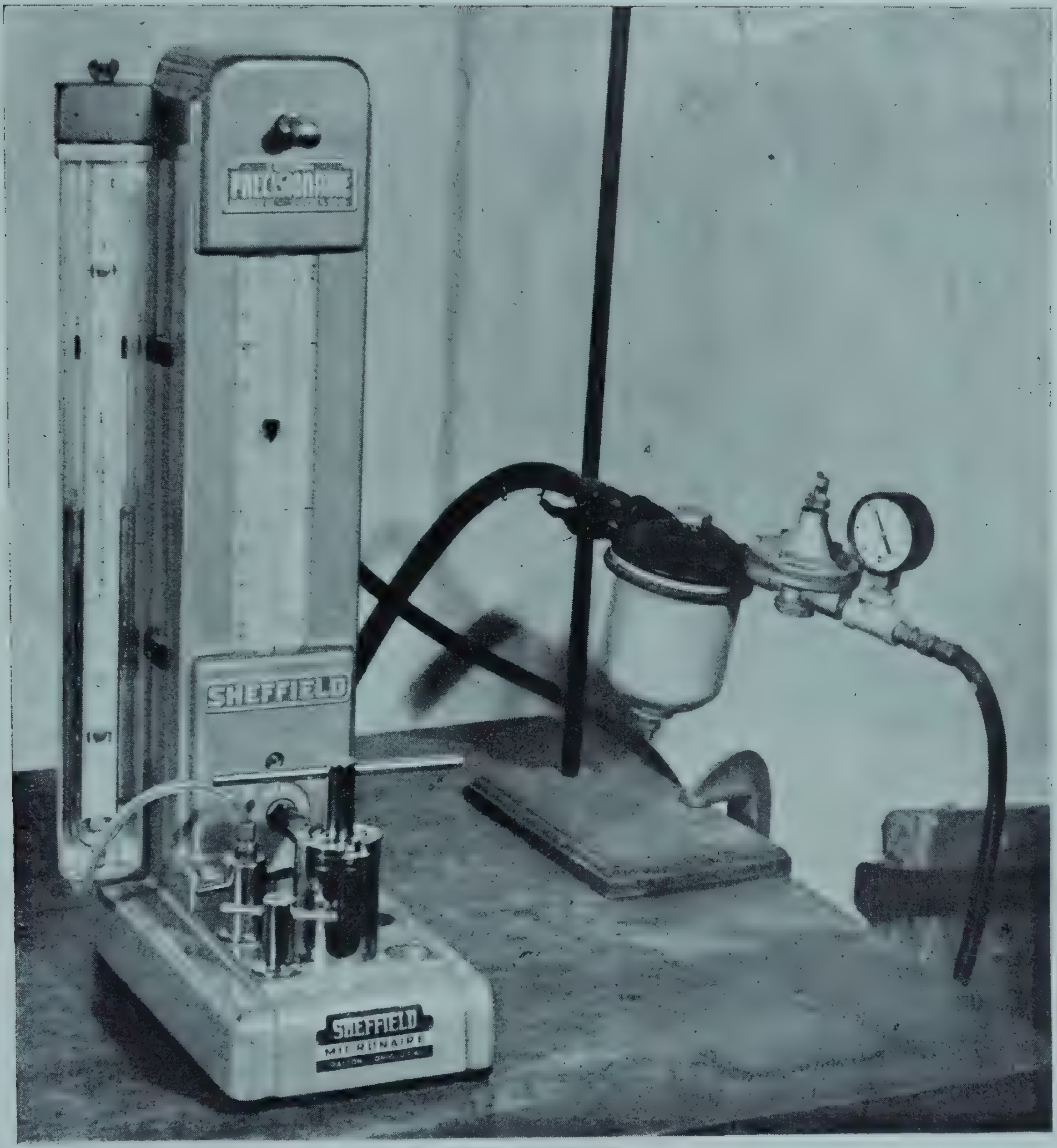


a. Ahmad-Nanjundayya Stapling Apparatus



b. Fibrograph

PLATE III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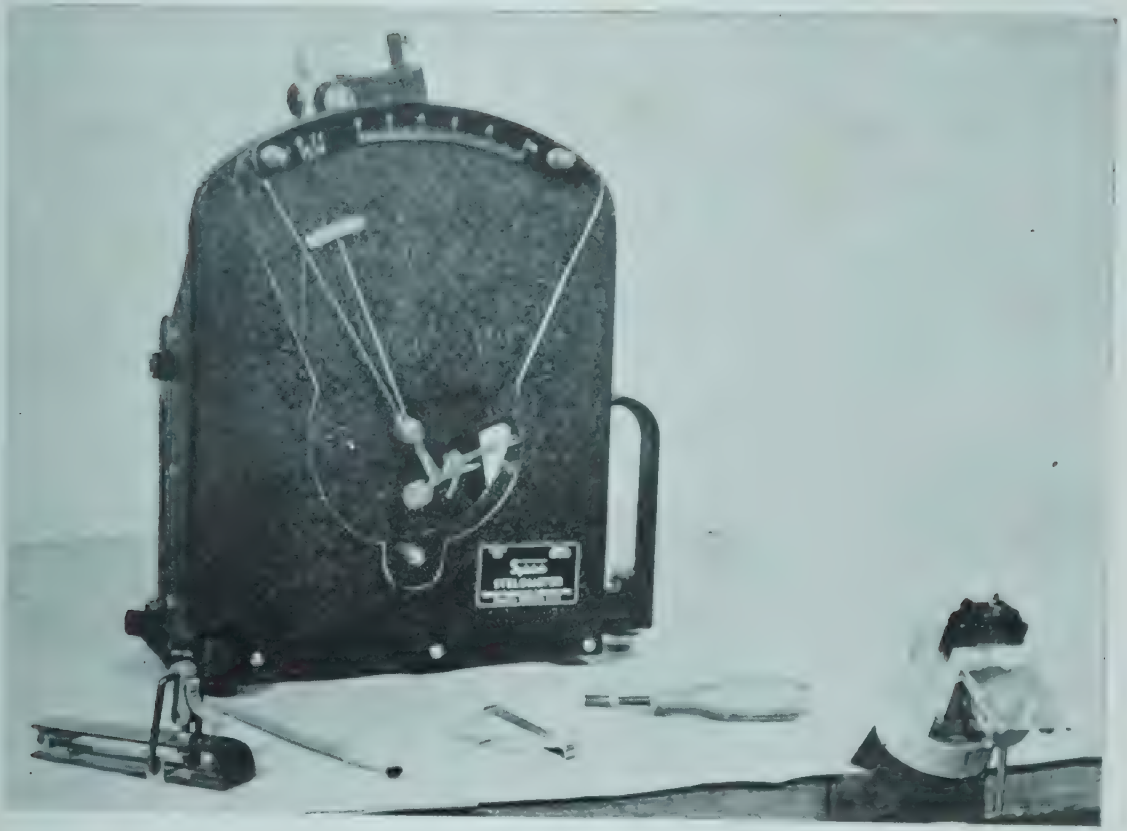

Stelometer

Table 5. Humidity Correction (Fibre Strength)

	30	40	50	60	70
0	1·218	1·146	1·083	1·026	0·975
1	1·211	1·140	1·077	1·020	0·970
2	1·204	1·134	1·071	1·016	0·965
3	1·196	1·127	1·065	1·010	0·960
4	1·189	1·120	1·059	1·005	0·955
5	1·181	1·114	1·054	1·000	0·951
6	1·174	1·107	1·048	0·994	—
7	1·168	1·101	1·043	0·989	—
8	1·160	1·096	1·037	0·984	—
9	1·153	1·089	1·031	0·980	—

Detection of Damages. As explained earlier, damage to the fibre may occur due to heat, micro-organisms, chemicals and machines. Early detection of the damaged fibre and identification of the type of damage are of great importance in the estimation of cotton quality. The extent of damage may be obtained by comparing the fibre properties and spinning performance in the undamaged and damaged states. But, for identifying the type and the origin of damage regular tests have to be carried out. A brief account of some of the tests is given below:

Tests for Surface Rupture: Damages involving the rupture of the fibre surface are best detected by the Congo Red Test. When the primary wall is ruptured, the congo red dye penetrates into the secondary wall and stains the cellulose deep red. The test is done by swelling the fibres in 11 per cent. solution of caustic soda and after washing them quickly, immersing them in a concentrated solution (2%) of congo red. The fibres are next washed and examined under the microscope after moutnting them in 18 per cent. caustic soda solution.

Other microscopical tests, such as the balloon test and the extrusion test, are also employed for this purpose.

Tests for Chemical Degradation: The chemical degradation of the cellulose is usually detected by the fluidity test. For this purpose, the viscosity of 0.5 per cent. solution of the material in cuprammonium hydroxide or cupriethylene diamine, is determined, and the reciprocal of viscosity expressed as the fluidity. Unprocessed cotton has a fluidity of less than three, and bleached cottons between three and eight. A higher fluidity indicates chemical damage, and at a value of 20 for cotton, the loss of strength would be about 25 to 30 per cent. Further, a rise of five in the fluidity corresponds to a loss of 10 per cent. strength.

Chemical degradation is also determined by the copper number, the carboxyl group estimation and the methylene blue tests.

Test for Honeydew: When aphids infest the cotton plant, the fibres get contaminated with their secretion, called the 'honey dew'. This is a sticky substance containing sugars, etc., and usually gives trouble in processing.

The presence and the amount of this honey dew can be determined by employing the usual reaction with Benedict's solution, with subsequent spraying of the cotton with phosphomolybdic acid. The contaminated areas give intense blue colour, while the other portions appear colourless.

Test for Microbial Damage: Fluorescence in ultra-violet light is used as a rapid test for microbial damage. From the colour of fluorescent spots, the type of organisms causing the damage can be identified.

EFFECT OF GENETIC AND ENVIRONMENTAL FACTORS ON COTTON QUALITY

Fibre properties, like strength, fineness, maturity, etc., are largely hereditary, and therefore, are characteristic of the variety. But wide variations in these properties occur due to different enviornmental conditions of growth in the same variety. A brief account of how these two factors affect the lint quality is given here.

HEREDITY

Extensive investigations have shown that fibres drawn from different regions of a seed surface have different physical characteristics. The fibres taken from the apical region (micropylar end) are shorter, coarser, stronger and more mature than those from the flanks or the basal region (chalazal end), and further, the former are also characterised by higher ribbon-width, lower number of convolutions per unit length and higher rigidity than the latter. The regional differences in the fibre weight and maturity are ascribed to the thinner population of fibres and earlier commencement of the deposition of secondary cellulose in the fibres at the apex than at the base, resulting in a larger quantity of available nutrition per fibre in the former region. On an average, a fibre at the base gets only three-fifths of the nutrition available to its counterpart at the apex.

Studies on the inheritance of fibre length, fibre weight per unit length and maturity have shown that a greater part of the variation in fibre weight per unit length is of genetic origin. In the case of the other two properties, the variation due to heterosis also is significant. The available evidence indicates that the ginning percentage is inherited in a complex way; a high value for it may result from lighter seeds, an increased number of fibres per seed or a high weight of the individual fibres. The genetic behaviour of lint percentage depends, therefore, on the inheritance of several main factors as well as on their inter-relation.

ENVIRONMENT

Locality and Season. When seeds of any variety are grown in different localities, fibre properties of the lint produced vary considerably; of these, fibre maturity is the most affected, and consequently, the fibre weight per unit length. In some cases, the mean fibre length is also affected. Besides locality, season also has a marked influence on the quality of the lint produced. For example, cottons grown in summer at Srivilliputhur (South India) were longer, finer and more mature than the same varieties grown in winter at Coimbatore in the same area; these differences were attributed to the higher temperature and greater solar activity at the former place than at the latter.

Water Supply. Several workers have studied the relationship between lint properties and water supply available to the plant during its growth. From his work on Egyptian cottons, Balls (1915b) concluded that the variation in fibre length depends also on the amount of water the plant had. The evidence obtained showed that the longest lint is produced by bolls which, at the time of irrigation, are very young and can take full advantage of the moisture available. Irrigation produces the maximum effect on bolls about the 15th day of development. But water-logged condition around the roots of the plants have a deleterious effect on lint length. In India, the influence of differential irrigation on fibre length was found to be small. However, according to Sen and Kar (1947), fibre development does not depend on temperature, but on the availability of moisture to the cotton plant. Lint length has been shown to increase if there is rainfall during the period of boll formation, but to decrease slightly with heavy rains before flowering. Scanty irrigation is responsible for immaturity, decrease in fibre length and increase in length irregularity.

Fertilizers. The effect of fertilizers on the quality of cotton lint raised in a soil is complicated, as it depends on several factors, such as the initial fertility, soil texture, moisture, etc.

It has been shown that there is no significant correlation between fibre length and the amount of nitrogen, phosphorus or potash present, or between fibre length and the rate of application of fertlizers, although somewhat contradictory results have been reported in this regard. In one experiment, five tons of farm yard manure per acre improved the fibre length of cotton to some extent, while in another, the application of 40 lb. of nitrogen per acre in the form of ammonium sulphate produced a similar effect. Fibre maturity was improved by the application of ammonium phosphate and sheep-dung. The chemical constituents of the fibre from plants grown on a deficient soil were markedly improved when suitable manures were added to it, but no change was observed when similar application was made to a soil which was initially fertile. Similar effect was also noticed in the case of fibre maturity.

Sowing Date and Spacing. The best sowing date for getting the optimum lint quality varies from cotton to cotton. The methods of sowing have no appreciable effect on lint quality.

Picking. The quality of lint picked at different intervals varies substantially. Generally, later pickings yield shorter and more immature lint than the earlier ones, and this is ascribed to the aging of the plant and the attacks on the plant by insect pests and diseases.

Stages of Multiplication. Experiments carried out by Rajaraman and Afzal (1941) on Indian cottons showed that there was practically no deterioration in the quality of lint up to the fourth stage of multiplication; but in a few cases, there was a slight fall in the later stages.

Insect Pests and Diseases. Cotton plant is attacked by many insects, like white-fly, pink and spotted bollworms, stem weevil, jassids, etc., and by diseases like wilt, root rot, *tirak*, etc. These infestations have adverse effects on the quality and yield of the cotton produced. It has been shown that a jassid attack caused a significant fall in the mean fibre length, fibre weight per unit length and maturity in susceptible varieties, while no such change was noticed in resistant varieties.

MOISTURE RELATIONS OF COTTON

Cotton is a hygroscopic material; it absorbs moisture when transferred from a dry to a humid atmosphere, and desorbs when the process is reversed. Hence, the quantitative estimation of its moisture content is essential both to research workers and the trade. In commercial transactions, cotton is bought and sold on the basis of weight and, therefore, a knowledge of its moisture content becomes necessary to assess its value. Further, the moisture content of cotton has a marked influence on the fibre properties, such as tensile strength, elasticity, rigidity, electrical conductivity, and also on the various processes during its conversion from fibre to fabric. Consequently, considerable work has been done on the various factors that influence the moisture relations of cotton, and on the effect of moisture on the fibre properties and fibre behaviour during processing.

Factors Affecting Moisture Content. The moisture content of a cotton depends upon the relative humidity and temperature of the surrounding atmosphere, and also on its previous history. It takes a long time for the fibre to reach equilibrium with the surrounding atmosphere in its moisture content, though the change is rapid in the initial stages. There are two possible values of moisture regain for a sample of cotton at a given relative humidity and temperature; a higher value if the cotton were previously exposed to a more humid atmosphere and a lower value if it were exposed to a drier atmosphere. In other words, the absorption and desorption curves are *sigmoid* in shape and follow distinct courses, as is characteristic of gels, and thus exhibit the phenomenon of *hysteresis*.

This was confirmed in a recent work on some Indian cottons, and the data given in Table 6 were obtained for the absorption and desorption of moisture at different relative humidities, calculated on the weight at 42 per cent. relative humidity.

On the basis of these data, a new equation for the calculation of the correction factor required to reduce the weight (w_h) of a cotton at any relative

TABLE 6. MOISTURE ABSORPTION AND DESORPTION VALUES (CALCULATED ON WEIGHT AT 42 PER CENT. RELATIVE HUMIDITY

Relative humidity (per cent.)	Absorption (per cent.)	Desorption (per cent.)
50	0·34	0·55
57	0·94	1·42
64	—	2·35
68	1·94	—
72	—	3·56
77	3·37	—
79	—	4·21
84	4·65	4·65

humidity (h) to that (w_{65}) at a standard humidity (65) has been obtained, viz.,

$$W_h = 1124.9489 - 1.686848\,h + 0.03740042\,h^2 - 0.000142368\,h^3\,.$$

The values for the correction factor, K_h, defined as $100\frac{(w_{65} - w_h)}{w_h}$, were calculated by making use of the above equation, and these values agree well with those obtained by previous workers, as can be seen from Table 7.

TABLE 7. VALUES OF K_h

Relative humidity per cent. (h)	Masson and Richards	Wallen	Urquhart and Williams	From the above equation
40	+2·3	+2·4	+3·1	+2·3
50	+1·4	+1·4	+2·0	+1·6
60	+0·5	+0·5	+0·7	+0·6
70	—0·7	—0·5	—0·7	—0·6
80	—2·2	—2·0	—2·5	—1·9

It has been shown that the amount of moisture held by a cotton does not vary appreciably over small ranges of temperature, if the relative humidity is kept constant; small changes in relative humidity, however, considerably alter the moisture content. The moisture holding capacity of a cotton decreases with an increase in temperature over the region 10° to 100° C. up to 80 per cent. relative humidity, when the relative humidity is kept constant. Above 80 per cent. relative humidity, it decreases only up to 50° C., after which it may increase with a rise in temperature from 60° to 110° C. This increase is ascribed to the possible exposure of new surface due to the swelling of the material. The maximum absorption of moisture, therefore, occurs at 100 per cent. relative humidity and at 100° C.

The moisture absorbing capacity varies in cottons of different origin, but not significantly enough to give any indication of their origin. These small differences are supposed to be due to the presence of non-cellulosic impurities. The moisture absorption does not seem to depend on fibre properties either.

Deformations of fibres appear to alter the moisture uptake of cotton. It has been observed that the desorption of moisture of a cotton yarn is considerably lowered when the yarn is placed under a stretching stress. The observed reduction in moisture retention may be due to the alignment and compression of structural elements.

Chemical treatments cause appreciable changes in the moisture relations of cotton. Mercerisation under tension generally increases its moisture absorbing capacity, and mercerisation without tension increases its capacity further. Scouring or soda boiling reduces the rate of absorption and increases the *hysteresis* effect. Blocking of the hydroxyl groups of cellulose by such processes as acetylation considerably reduces the absorptive power of cotton.

Theory of Sorption. The hygroscopicity of a textile fibre depends upon its structure and chemical composition. The association of water molecules in some form of chemical combination with the cellulose molecules is the first phase of absorption, while in the second phase, the water is held loosely in the internal structure by physical forces. The sorptive capacity of cellulose fibres is now known to depend upon the amorphous regions of cellulose, close relationship having been observed between the amount of moisture absorbed and the total amorphous portion. The cellulose molecule contains a number of free hydroxyl groups, particularly in the amorphous regions, and these are capable of uniting with molecules of water by hydrogen-bonding.

The absorption of water by cellulose is accompanied by the evolution of heat, especially in the initial stages of absorption, which diminishes rapidly with further absorption. The moisture initially absorbed forms a homogeneous system with cellulose due to hydrogen-bonding when heat is evolved, but the water absorbed later is held in the inter-spaces by capillary forces, contributing very little to the heat of sorption.

The phenomenon of *hysteresis* is supposed to be due to the absorbing surface being less active during absorption than during desorption, as a consequence of the mobility of active groups in the amorphous region of the fibre.

Fibre Properties and Sorption. The cotton fibre swells when it absorbs moisture. This swelling is greater laterally than longitudinally due to the cellulose chains showing preferred orientation in the direction of the fibre axis. In passing from dry to wet state, cotton fibre increases in length by about 1.2 per cent. only, whereas the lateral expansion is about 14 per cent. The swelling increases with a rise in temperature and relative humidity, and is maximum at 100° C. and 100 per cent. relative humidity. The chemical reactivity of cotton, such as dye absorption, hydrolysis, etc., depends, to a large extent, on the swelling achieved by absorption of water.

The strength and extension of individual cotton fibre, as well as of yarn, are influenced, to an appreciable extent, by relative humidity. The fibre saturated with water is about 20 per cent. stronger than when it is air-dry. The strength of the cotton fibre depends essentially on the length of its chain molecules and their orientation. The cellulose molecules in cotton are quite long and pass through many crystalline and amorphous regions, and there is little chance of inter-molecular slippage due to external stresses. When water is absorbed in the amorphous regions, better alignment of the chains in the direction of the fibre axis takes place, and there is a uniform internal distribution of the stress throughout the fibre. This results in greater wet strength. Whereas, in the case of rayon where the chains are very short, the chances of slippage are great due to the penetration of water molecules, which weakens the lateral cohesion. Consequently, the wet strength is lower than the dry strength.

Moisture influences the torsional rigidity of the fibre to a great extent. The rigidity is appreciably lowered in the wet state, and is only about one-eighth of its value in the bone-dry state. This effect is largely due to the water molecules attached to the hydroxyl groups of the cellulose molecule.

Increase in the moisture content of the fibre causes partial elimination of convolutions and also of reversals; but on drying, they re-appear. The refractive indices of cotton fibre change with its moisture content, according to Gladstone and Dale's Rule for homogeneous mixtures, up to 20 per cent. regain.

Moisture has an important effect on the electrical properties of cotton. In a dry atmosphere, it is possible for the material to become so highly charged that carding and spinning operations become difficult, but these troubles are avoided if the relative humidity of the atmosphere is increased, as the conductivity of cotton increases with an increase in the relative humidity.

Effect on Processing. Fibre properties of cotton are thus influenced by the moisture conditions of the surrounding atmosphere. It becomes necessary, therefore, to maintain proper conditions of humidity and temperature at every stage of processing. Cotton can be manipulated more easily under controlled atmospheric conditions. Controlled humidity and temperature at the optimum level result in: (*i*) the reduction of the fly and other wastes; (*ii*) production of yarns of uniform count and of fabrics of constant weight per unit area; and (*iii*) reduction of troubles due to static electricty, thus improving the production both in quality and quantity. The optimum relative humidities recommended for various stages of processing are as follows:

	Relative humidity (per cent.)		Relative humidity (per cent.)
Blowroom	40 to 45	Roving	50 to 60
Carding	45 to 55	Spinning	50 to 65
Combing	55 to 65	Weaving	70 to 80
Drawing	50 to 65	Cloth room	65 to 75

ESTIMATION OF RAW COTTON QUALITY

Cotton is used for many purposes and each one may demand a particular characteristic or a combination of several characteristics. 'Cotton quality' is a term which may be used to express a variety of different fibre properties, which usually determine thes pinning value of the material. A good quality cotton generally means a clean lint, having a good bloom and regular appearance, and a satisfactory staple length, fineness and strength. The ultimate aim is to get a clean yarn of good strength and optimum fineness from the raw material, with minimum processing troubles and at a minimum cost. As it takes a long time to get the raw material actually spun to assess its value, the quick estimation of 'raw cotton quality' becomes important and necessary. Different methods are used by the trade and the laboratory for this purpose, which are briefly described below:

COMMERCIAL METHOD OF ESTIMATION OF QUALITY

The buying and selling of cotton are mostly based on the grader or classer's judgment of the grade and staple of cotton. Grading describes the cotton. The chief factors which determine the grade of a cotton are: (*i*) amount of foreign matter, such as seed coat fragments, leaf bits, etc.; (*ii*) colour or bloom; and (*iii*) ginning preparation. The amount of waste due to the presence of foreign matter in the lint depends upon the variety of cotton, its growing conditions, the mode of picking, the method of ginning, etc. This waste assumes importance because of the expense involved in its removal and the trouble which it causes during processing. The amounts of waste generally associated with the nine grades employed for American Upland cottons are given below:

Grade	1	2	3	4	5	6	7	8	9
Waste (%)	5.5	5.5	6.0	6.3	7.5	8.1	10.4	11.9	14.4

Raw cotton is normally light to dark cream in colour, depending on the variety and environmental conditions of growth. Colour is a factor to be considered in the manufacture of fabrics and yarns for certain specific purposes. Low grade cottons have a bluish or grey colour, and are difficult to bleach or dye in certain shades, particularly light ones. The colour of a cotton is influenced by its age and chemical composition, and the presence of micro-organisms.

Preparation refers to the quality of ginning. It indicates the uniformity of fibre arrangement in the sample and whether the fibres have been damaged by gin-cutting, nepping or napping. When properly ginned, the fibres have a uniform appearance; but when ginning is poor, some of the fibres are grouped together in the form of string like tufts, unevenly distributed throughout the sample, giving it a rough appearance. Well ginned cotton is clean and reasonably free from motes, leaves, trash and sand, and tangled, matted and cut fibres, and offers least resistance to processing. Badly ginned lint is responsible for: (*i*) excessive waste; (*ii*) manufacturing difficulties; (*iii*) low strength of yarn; and (*iv*) lack of appearance and uniformity of the finished product.

The staple of a cotton is an integrated impression of staple length, and character, which comprises strength, uniformity of staple length, drag, feel, etc.

The grader, by virtue of his long experience, is able to estimate the grade and staple of a cotton visually, with or without the help of a standard. Obviously, such an estimation depends upon the visual impression and the perception of the hands of the grader, which in turn are likely to alter with his mood, atmospheric conditions of humidity and temperature prevailing at the time of grading, etc. Nevertheless, his judgment is mostly correct in the case of cottons which he usually handles from year to year; but it is often erroneous in the case of new and improved varieties.

Generally, length, with which fineness is associated, plays an important part in the estimation of quality, and decides its price also. The grader estimates fibre length by hand stapling. No two graders staple cotton the same way, but certain features are common to all hand-stapling methods. A lump of cotton is gripped by both the hands touching each other and broken gently by pulling them apart. One portion is discarded, while the fringe of fibres from the other is pulled out between the thumb and the fore-finger of the free hand. This tuft is then doubled and drawn between the fingers several times in order to stretch and make the fibres parallel. After making an even edge on both sides of the tuft, it is placed on a black velvet and estimated for staple length with or without the help of a scale.

It is obvious that this method is open to subjective errors. In the process of stretching and parallelising, a certain amount of short fibres may be rejected. Further, in making an even edge on both sides of the tuft, some long fibres protruding from both ends are eliminated. The process of preparing the tuft may make the sample lose its representative character. In this connection, it would be interesting to reproduce the results of an experiment conducted by the United States Department of Agriculture, in which the fibre length distribution of a sample of tuft prepared by the grader is compared with that of the actual one (Fig. 13). It may be seen from this figure that the grader's sample is actually deficient in the longest and the shortest fibres. There are other variable features even in the measurement of the staple length, such as the marking of the two edges to represent the typical length of the tuft, which may vary from person to person.

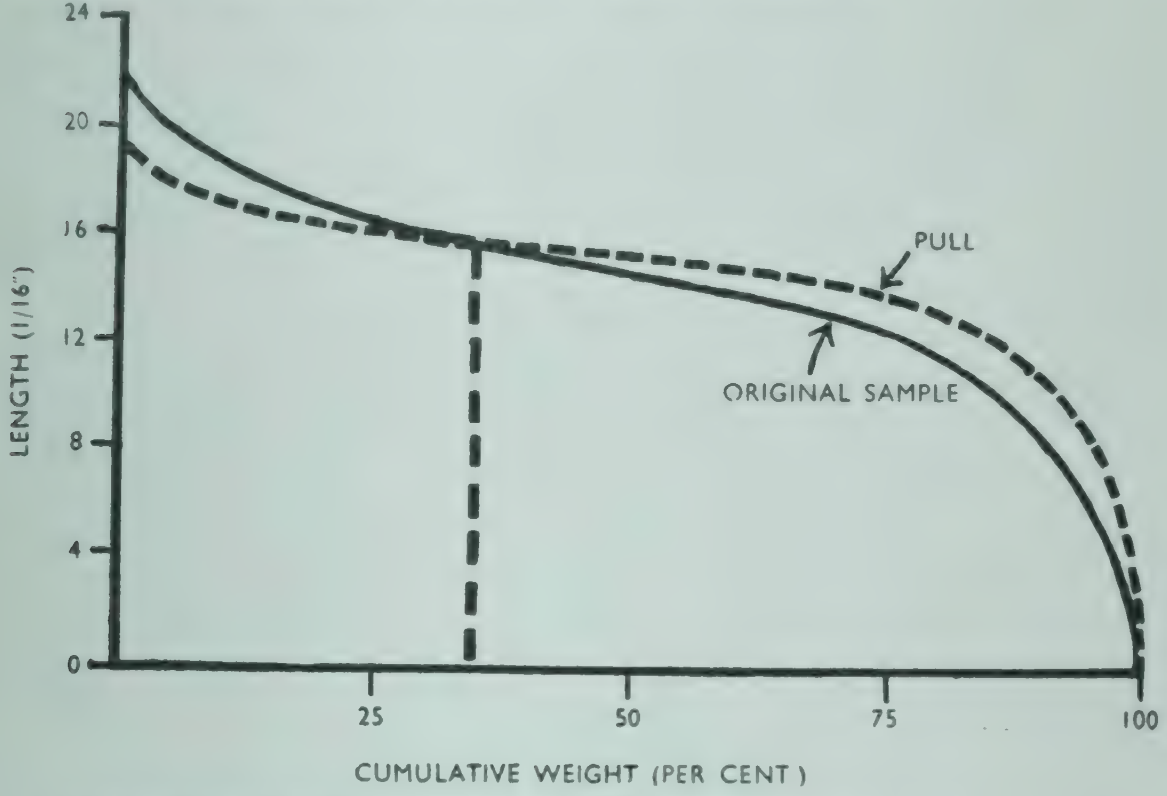

Fig. 13. Fibre Length Distribution of a Grader's Pull Compared with that of Actual Sample

LABORATORY METHODS OF QUALITY ESTIMATION

The laboratory methods of estimating cotton quality are, on the other hand, more objective; the personal element is eliminated to a very large extent and each property is accurately measured and expressed in precise fundamental units.

Among the instruments that can be used for determining the grade of a cotton, are the Shirley Analyser and the Nickerson Hunter Colorimeter. The Shirely Analyser helps to determine the waste and foreign matter contained in a sample of cotton; the colour of the cotton can be determined by using the Nickerson Hunter Colorimeter, which is a photo-electric optical instrument.

The staple of a cotton, by which is meant an integrated impression of its fibre properties, is determined in the laboratory by carrying out the various tests for fibre length, fineness, tensile strength, maturity and friction. The methods of these tests have already been described.

The laboratory tests, in providing an objective assessment of the quality of the material, are as valuable to the cotton breeder as to the trade and industry, especially in the early stages of his experimentation, when selection has to be made, either in reference to one particular property, such as staple length, or in respect of the general quality of the lint, from among a large number of new starins. Without these tests, the breeder would be at a loss to know which of his strains is better. Further, the fibre tests carried out in the laboratory provide data for the study of relationships between the fibre properties and the spinning value of a cotton.

SPINNING VALUE OF COTTON

Estimation from Fibre Properties. The estimation of the fibre quality, it was mentioned earlier, is taken to mean the assessment of various fibre characteristics that determine the quality of the yarn. Apart from the influence of the mechanical treatment to which a cotton is subjected, the characteristics of the yarn depend on the properties of the fibre from which it is spun. It is, therefore, important to know the types of relationship that hold between the yarn characteristics and fibre properties, and the manner in which the fibre properties are modified by the treatment given to the cotton.

It is a universal practice to regard the yarn strength or the finest count that could be spun economically with a specified strength as the most appropriate single index of the spinning value of a cotton, in addition to other factors, such as yarn appearance, neppiness, ease of processing, ends down in spinning, etc. Extensive investigations have been carried out by many workers for over three decades in the United Kingdom, the United States and India to correlate the measurable fibre characters, such as staple length, fineness, maturity and strength, to its spinning value or quality. Gurney (1925), Kohler (1934), and Sullivan (1942) derived theoretical relationships, based on some assumptions regarding the shape of fibres and structure of yarns, which are difficult to be achieved in practice. Most of the subsequent work has been confined to an emperical method, in which a large number of cottons are tested for spinning value and fibre properties, and a statistical relation connecting the two factors worked out.

On *a priori* consideration, the strength of yarn should depend upon that of the individual fibres that compose it. Early studies, however, gave paradoxical conclusions to show that these two factors were negatively correlated. This was explained by the fact that stronger fibres were also coarser and, consequently, less number of fibres would be present in a cross-section of a yarn of any count than the number of weaker and finer fibres. This anomaly was remedied by allowing for the number of fibres in the yarn cross-section, and a positive correlation coefficient between the two factors was obtained. This relationship improves considerably by correlating bundle strength, instead of single fibre strength, to yarn strength. It should, however, be noted that the aggregate strength of fibres composing a yarn is only rarely realised in the yarn strength because of the slippage of fibres, the proportion of fibres that break or slip depending upon the twist inserted in the yarn and the properties of the fibre, such as clinging power, length, etc.

The importance of fibre fineness in the determination of the spinning quality was emphasised by Balls (1928) and Morton (1930). Balls (1928) stated that from the point of view of yarn strength, the most important fibre properties are the intrinsic strength, fineness and slipperiness.

Although clinging power should also influence yarn strength substantilally, the relationship between these two properties was observed by Navkal and Turner (1930) to be weak. Their studies revealed that there is a tendency for those cottons which have high clinging power in relation to their length and fineness to spin comparatively higher counts, but the influence of this property on the spinning value is less than that of fibre length and fibre weight per unit length.

An extensive statistical study has been made with the data collected for more than 25 years on hundreds of Standard Indian cottons, which are, every year, tested for fibre properties and spinning value. Several regression equations, connecting the spinning value of a cotton and one or more of its measurable fibre properties, have been worked out. A regression equation, which is of wide application to a majority of Indian cottons, is given below :

$$X_1 = 78.9\,X_2 - 79.2\,X_3 - 24.8,$$

where X_1 = H. S. W. C*., X_2 = mean fibre length (inch), and X_3 = mean fibre weight per inch (10^{-6} oz.).

From this study, it was observed that the mean fibre length contributes most to the spinning value of Indian cottons, unlike the case of Egyptian cottons where the fibre fineness is more important than the fibre length. But above a certain limit, the importance of the fibre length decreases as the staple length of cotton increases.

Prediction formulae, applicable to certain classes and botanical species, have also been worked out, from which it is possible to estimate the spinning value with a greater degree of accuracy than from the general formula.

In this connection, it may be of interest to note that a general theoretical solution of the problem of estimating the spinning quality of any textile fibre from its fibre properties was worked out by Spencer Smith (1947), who obtained a linear relationship between single thread count-strength-product and the square root of the count. This was found to hold good in the case of flax yarn. Recent work done by Morton and Nanjundayya (1949) showed that there is a similar linear relationship in the case of 1-7/16″ Fibro yarn also, when spun on the cotton system. This has yet to be experimentally verified for cotton and other staple fibres.

In this method, the two parameters, which determine the spinning test line, viz., the intercept (Q_o) of the straight line, showing the relation between the single thread count strength product and the root count, on the former axis and its slope (k), are shown to be related to fibre properties. Thus, the spinning characteristics of a cotton or any other textile fibre may be completely determined. The work of these authors also showed that (Q_o) is more or less related to the Pressley bundle strength index. In short, it appears that if two regression equations correlating (Q_o) and (k) separately with the appropriate fibre properties are worked out, it is likely that further improvement may be made in the prediction of spinning value.

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* Highest standard warp count, which is defined as the finest count that could be economically spun with a twist multiplier of 4·0 to give a standard lea strength.

Further, some relationships between cotton fibre characteristics and factors, such as the appearance of yarn, percentage of processing wastes, number of neps in 100 square inches of card web, optimum roving twist, yarn twist, etc., have also been worked out.

As regards yarn appearance, it was observed that fibre immaturity, notably in its longest fibres, is mostly responsible for neppiness in yarn, and that deformities and breakages of fibres during processing also help in nep-formation. Foreign matter, such as cut seeds, leaf bits and fragments of jute fibres, also contributes to the ugly appearance and neppiness of yarn. Processing wastes are largely governed by grade, maturity and uniformity of staple of the cotton.

Estimation of Quality from Yarn Characteristics. The best method of determining the spinning value of a cotton, it was stated earlier, is by actually spinning it and studying its yarn characteristics. This would enable a better estimation of the quality of the raw material.

The spinning process consists of three stages: (*i*) opening of the raw material, freeing it from foreign matter and mixing it thoroughly; (*ii*) drafting and parallelising of the fibres; and (*iii*) twisting of the fibres into a yarn. Cotton is first passed through different kinds of opener, where it is beaten well and separated from trash and foreign matter. The fairly clean, loose cotton is then converted into a compressed sheet, called lap, in the scutcher. The lap is then transferred to the carding machine where the fibres are separated and mixed thoroughly, and the last traces of impurity and neps are removed. The carded fibres come out in the form of a thin web, which is condensed into a sliver. The carded sliver is combed, if required, in the case of finer cottons before passing it on to the next process of drawing.

Combing is done in order to: (*i*) remove the short fibres and increase the regularity of staple length; (*ii*) bring about better parallelisation of fibres composing the yarn; and (*iii*) remove the impurities that are still present in the carded sliver, so that better lustre of the yarn could be obtained.

With the card sliver as the foundation of yarn manufacture, every succeeding process in cotton spinning has a two-fold object to perform. The first is to carry the material a little further in the constructive process and the second is to minimise the defects of the preceding stages. The object of drawing, which follows carding, is: (*i*) to obtain a parallel arrangement of the fibres contained in the sliver; and (*ii*) to make it even. The dual action of the process is achieved in the drawframe by the principle of doubling and drafting.

The subsequent processes in the fly frames are a continuation of the drafting process, with or without doubling, the aim being the attenuation of the sliver with a corresponding reduction in thickness until a state of fineness of the yarn is achieved. Since the process cannot be achieved in one step with ordinary fly frames, the operation is carried out in stages. The drafting in the semi-final stage is accompanied by some twisting, to impart sufficient strength to the roving to withstand the strains of the next operation.

The final stage is the actual spinning in the ring frames, when the roving is drawn out in the form of a yarn of requisite fineness, and necessary twist is imparted, preserving, as far as possible, the uniformity of the original roving.

Yarn Characteristics

Yarn Strength. The characteristics of a yarn spun from a cotton are closely related to its fibre properties. The method most commonly employed for estimating the strength of a yarn is the lea test. Despite its wide popularity, this method suffers from several defects. In the laboratory, it is usual to supplement it with the single yarn strength test. The latter, however, requires a great deal of time, as a large number of tests are necessary to avoid sampling errors. The third method, the ballistic lea test, which measures the work of rupture, is much more sensitive to changes in relative humidity than either the lea or the single thread strength test.

The skein or lea test is carried out on a pendulum type tester, 1.5 yard perimeter skein of 120 yards being taken for the test. The single thread test involves the breaking of a single strand of yarn between the jaws of a tensile testing machine. The instrument generally employed for the single thread test is the Goodbrand's Single Thread Tester. Other instruments, such as the Moscrop Single Thread Tester, the Schopper Tester, the Scott's Inclined Plane Tester, and the Uster Single Thread Tester, are also used.

Yarn quality is generally assessed by the lea strength and single thread strength. The standard strength for a particular count is somewhat arbitrarily fixed and depends, to a large extent, upon the particular use to which the yarn is subsequently put. It is well-known that the strength of a yarn mostly depends upon its count and the twist inserted in it, in addition to the strength of the fibres composing it. Good strength combined with elongation gives a high work of rupture, which enables the yarn to sustain sudden impacts. For many purposes, however, strength is not the only ultimate aim; a part of the strength is sacrificed sometimes to get greater pliability and softness. In addition to strength, other qualities expected in a good yarn are evenness, freedom from neps, elasticity, lustre, etc.

Elongation. The elongation of a yarn is generally determined simultaneously with breaking strength in the single thread strength test. The instrument is provided with a gauge for denoting the elongation at break, which is also automatically recorded on a chart to permit its reading either at break or at any other selected load.

Yarn Number. The yarn number is a measure of the linear density or fineness of the yarn, and denotes the number of 840 yard-lengths in a pound, in the case of cotton. The actual determination of the count is done along with the strength test, by weighing the lea or half lea broken on the lea or ballistic tester.

Yarn Twist. The amount of twist in a yarn is generally expressed as the number of turns per inch; but it may also be expressed by the helix angle in a structure of known diameter. The number of turns per inch is determined by counting the turns in a measured length of a yarn, as it unwinds in a twist tester. The instrument consists of a counter, and two clamps, one of which is adjustable and rotatable in either direction, and the other fixed. The yarn to be tested is gripped and unwound between the two.

Yarn Irregularity. Variation in uniformity is an important characteristic of a sliver, roving or yarn, since an even sliver may be expected to give an even yarn which will be stronger and can be more efficiently spun and woven, with fewer breaks or warp streaks. Much of the variation in the cross-sectional weight of the yarn originates in the early stages of processing, particularly in the drawing frames, and is carried forward and amplified by each drafting process. Variation in the weight per unit length is fundamental, and variations in other yarn properties, like diameter, count, twist per inch, strength, hairiness, etc., depend on it.

Variation in the weight per unit length of the yarn can be assigned to the properties of the raw material and the short-comings of the yarn making machinery. Cotton is a very variable material and the variations in its length, fineness, etc., which are enormous, bring about the irregularity of the yarn spun from it. Other fibre characters, such as crimp, shape of the cross-section, friction, elastic properties, electrical conductivity, etc., may also contribute to yarn irregularity, because they may assist or impede the drafting in some way or the other.

The drafting waves are mostly due to short fibres in the cotton, which during their passage through the drafting rollers, are, for a time, out of the control of both sets of rollers. The drafting waves produced in the early stages of drawing are considerably extended in subsequent operations, though their amplitudes are reduced by the doubling which takes place in the process, and those produced in the later operations become more prominent in the final yarn. The waves produced in the spinning process are the most prominent of all and they are responsible for a great deal of the short term variations in the yarn. As counts become finer, yarn irregularity increases, irrespective of the manner of processing or the state of perfection of the machinery.

Defects in card clothing, eccentricities in rollers, broken teeth on draft

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wheels, worn roller coverings, defects in roller bearings, etc., are some of the mechanical causes of yarn unevenness. Improper humidity conditions and inefficient operation of the machinery add to it.

Of the many instruments employed for the estimation of yarn evenness, the Uster Evenness Tester and the Fielden Walker Evenness Tester have become popular. They are electronic instruments, equipped with paper strip recorders for recording the evenness fluctuations of the material as a function of its length and an integrator which evaluates the recorded evenness graphs. The material to be tested passes through the plates of an electrical capacitor, and as it moves through, it changes the capacitance by an amount proportional to the weight of the material between the plates. Since the dielectric constant of non-conducting textile materials is several times that of air, a careful measurement of capacity at any given instant during the test indicates the mass of the material between the plates. There is an arrangement in the Uster Tester for passing slivers, rovings and yarns between the plates of the condenser at different speeds.

There are other evenness testers, such as the Saco Lowell Lap Evenness Tester, for measuring the evenness of scutcher laps, with whose help defects in openers, pickers and evener motions can be rectified and uniform laps fed to the card.

Neps. A desirable feature of any cotton yarn is its relative freedom from neps. Neps not only mar the appearance and lower the strength of a yarn, but cause breakages during processing. Also, in the finishing processes of fabrics, such as dyeing and printing, places where neps are present react differently from the bulk, resulting in spotty and streaky finished materials.

Neps are formed as a result of: (*i*) inherent propensity of a cotton to make neps; and (*ii*) type of processing treatment it has received. Detailed studies have revealed that a majority of neps is formed from: (*a*) matted fibres; (*b*) immature fibres; and (*c*) damaged normal fibres or kinked and spurred fibres. During the opening process, neps are formed due to the entanglement of fibres and as a result of friction, or curling and folding over of fibres. They could be considerably reduced with good carding, by taking suitable measures, such as higher licker-in speeds, closer settings and proper grinding schedules, to the extent of 70 per cent. and more. Neppiness is generally expressed in terms of the number of neps per gram of a sample, or in a yard of the yarn, or the number of neps per 100 square inches of the card web. Comparison of card webs and yarn wound on black cardboards with the standards prepared by the A.S.T.M. is sometimes adopted as a quick method of grading cottons and yarns according to their neppiness. There are several instruments, such as Readex, Template, Nepotometer and Neptel, for counting the neps in cotton and yarn.

A.S.T.M. = American Society for Testing Materials.

Highest Standard Count

Since most of the cotton is spun into yarn, it has been generally accepted that the spinning value of a cotton represents its quality. The question as to how best the spinning value is assessed has not yet been fully answered. There are mainly three ways in which the relative merits of different cottons can be assessed: (*i*) by spinning all cottons to one count with the same twist multiplier and judging the spinning performance from the lea strength or count strength product (C.S.P.); (*ii*) by spinning all cottons into two known counts and a third count, its value being based on the lea strengths of the two known counts; and (*iii*) by deriving one count having a standard strength, which can be economically spun, the value being based on the lea strengths or count strength products of three or more counts.

The first method has been adopted in Egypt, where the count strength product for 60s yarn, spun with a twist multiplier of 3·6 under standard atmospheric conditions, is used to judge the spinning value of a cotton. This presumes that all cottons are spinnable to one common count, which obviously, is impossible except when their qualities lie within reasonable limits. Although this condition may be satisfied for Egyptian cottons, it will not hold good for Indian cottons, as they have a very wide range of fibre characteristics and spinning values, varying from 6s to 50s counts. Spinning all cottons falling within this wide range to a common count may result in over-estimating fine cottons, which could be spun to very fine counts, and under-estimating short and coarse cottons.

The second method is followed in the United States. Here, the twist multiplier employed for spinning the yarns is not the same in all cottons and is varied according to the staple length of the cotton—higher the staple length, lower the twist multiplier used. Although it is possible to judge the spinning performance of a cotton by this method, it cannot be used to ascertain the comparative performance of different cottons.

The third method, which has been adopted at the Technological Laboratory, Bombay, consists in deriving an integrated value based on the performance of a cotton in three counts; it is a single index which assists in ranking the cottons according to their quality. This method is described below.

Standard values for lea strength for various counts are fixed as follows:

Count (C)	Breaking Strength (lb.) (S)	Count Strength Product (C.S.P.)
14	90	1260
16	81	1296
18	73	1314
20	67	1340
22	62	1364

(*Contd.*)

Count (C)	Breaking Strength (lb.) (S)	Count Strength Product (C.S.P.)
24	58	1392
26	54	1404
28	51	1428
30	48	1440
32	46	1472
34	44	1496
36	42	1512
38	40	1520
40	39	1560
50	33	1650

These standards are obviously arbitrary, but they represent the average qualities of the types of cotton that are used in the mills. The plot of count strength product against count is a straight line, AB (Fig. 14). Further, as the count becomes finer, the standard count strength product increases instead of being constant, which means that a higher standard of quality is demanded of finer counts.

A cotton, whose spinning value is to be determined, is spun into a count, with a twist multiplier of 4·0, which is well within its spinning capacity. On the basis of the lea strength of this count, two further counts are spun with the same twist multiplier (4·0) as before. Thus, there will be three counts and their respective count strength products. A plot of the count *versus* count strength product for these three counts is made on the same graph paper where the standard count strength product *versus* count line is plotted (Fig. 14). Let these points be D, E and F. The standard spinning test line AB has an opposite trend to that of the experimental spinning line DEF. The count, corresponding to the point of intersection between the standard spinning test line and the actual spinning test line, is taken to be the highest standard count to which this cotton could be spun with a twist multiplier of 4·0. It will be seen from the figure that if any cotton is spun into a count lower than the highest standard count, the count strength product realised would be greater than the standard value given for that count in the above table and *vice versa*. Also, the highest standard count would vary with the twist multiplier employed for spinning the three counts. It is, therefore, necessary that, in order to get the comparative spinning values of different cottons, they should all be spun with the same twist multiplier.

It has been found from actual experience at the Technological Laboratory, Bombay, that this highest standard count gives a good index of the spinning value of a cotton. In this connection, it may be mentioned that the Shirley Institute, Manchester, follows a somewhat similar method except that it differs in two respects; firstly, the standard spinning test line is taken to be parallel

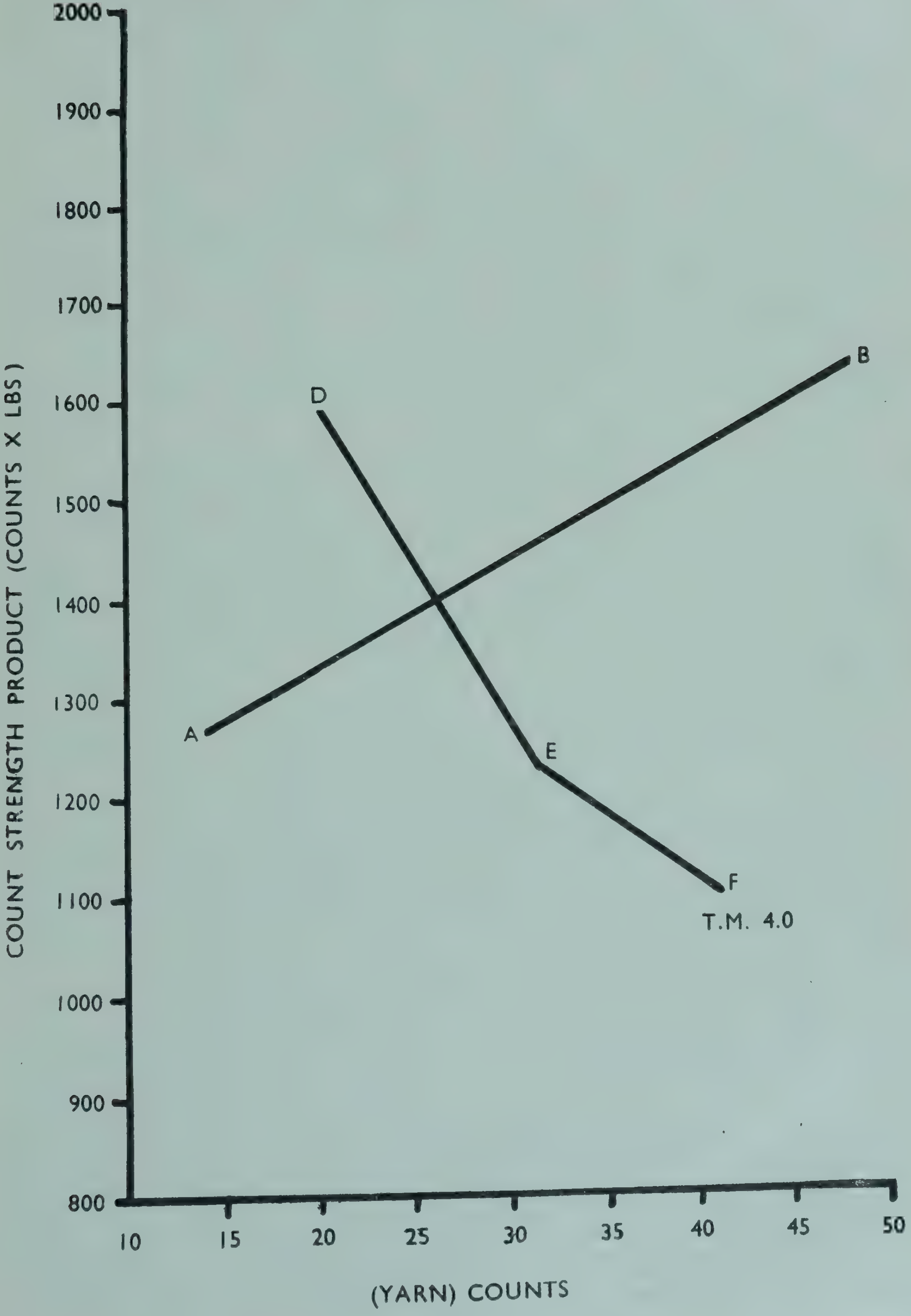

Fig. 14. Estimation of Highest Standard Count

to the count axis, which means that the standard count strength product for all counts is the same, and secondly, the twist multipliers employed for different cottons are different. The standard count strength product is taken to be 2,000 for carded yarns and 2,250 for combed yarns. This standard, however, is too severe for cottons spinning less than 20s.

Small-Scale Spinning Technique

Though many attempts are being made to arrive at an accurate prediction of the spinning value of a cotton from its fibre properties, the surest test of the processing qualities of a cotton is the actual spinning itself. Regular spinning tests, however, take a great deal of time and require large amounts of cotton, and hence, such tests are not generally done to determine cotton quality. But in recent years, techniques suitable for the production of yarn from small samples have been developed, which enable the quick determination of the spinning quality of a cotton.

A miniature plant has been designed by the Shirley Institute, by which spinning tests from samples of raw cotton weighing only 42 grams can be made quickly. It is claimed to be wide in its scope, both with regard to the range of staple lengths it can handle and the counts it can spin, and it is possible to test the samples in an hour. The plant has been developed as a testing unit and, as such, it is said to give consistent and reproducible results, enabling the quick estimation of the spinning value of different cottons and blends.

A technique developed at the Technological Laboratory, Bombay, uses a 60 gram sample of cotton and the regular carding and spinning machinery with suitable modifications, but the opening of the cotton is done by an ordinary bow used in hand-spinning. The strength results of the yarns obtained by this technique show high correlation to those of the yarns spun on the regular spinning unit, but the yarns spun from small samples are about seven per cent. higher in strength than those obtained by the standard spinning technique with 10 pounds of cotton.

IMPORTANT INDIAN COTTONS AND THEIR FIBRE PROPERTIES AND SPINNING VALUES

The problems connected with the cultivation of cotton in India, are somewhat different from those of other countries, such as the United States and Egypt, where cotton is grown in more or less compact areas, which make it possible to raise large quantities of one variety. In India, it is grown on a vast area which has widely varying climatic and soil conditions, thus making it difficult to raise a single variety over a large area. Therefore, it has become imperative to grow a large number of varieties in this country, each variety being suitable to a particular tract from the point of view of yield and quality. Consequently, one would find cottons grown in India possessing a wide range of fibre properties and spinning values.

Before the establishment of the Agricultural Departments in the various States in India, different types of cotton used to be grown by the cultivators, regardless of whether they were suited to a particular tract or not. The Agricultural Departments, therefore, began systematic work, with a view to evolving new and improved varieties for each area. When one such variety was evolved and recommended for cultivation, in course of time, the farmers in the area grew it in their own fields extensively, as it brought a higher monetary return to them than before, and such varieties formed the commercial crop of India. It is these improved varieties that are maintained as standard cottons in the experimental stations located at different cotton growing tracts of India.

They are grown each season from pure seeds and under as nearly the same conditions as possible to serve as standards of reference. These standard cottons generally remain unchanged, but when one of them has definitely proved unsuitable, or has gone out of cultivation, or has been superseded by a better variety, it is omitted as a standard, or a new one is substituted. These standard cottons include cottons belonging to *G. arboreum*, *G. herbaceum* and *G. hirsutum* species.

The standard cottons are subjected to a large number of tests at the Technological Laboratory of the Indian Central Cotton Committee in each season, along with the new and improved varieties evolved by the cotton breeders, the former serving as standards of reference. These standard cottons, therefore, represent the important cottons produced in India at present, whose fibre properties and spinning values are given in Table 8.

APPLICATION OF STATISTICS TO COTTON TECHNOLOGY

One of the main difficulties in any investigation on cotton is the enormous variability of the raw material. A single seed of cotton contains between 5,000 and 15,000 fibres on its surface, a boll between 100,000 and 600,000 fibres, and a bale between 25,000 million and 100,000 million fibres. This is not all. There is a wide variation in the fibre properties also. Even on a single seed, fibres drawn from different portions vary greatly in their properties. Again, even a small sample of cotton may contain fibres varying from 1/8 to 2.5 inches in length, 0·1 to 15 grams in single fibre strength, 10 to 20 microns in diameter, etc. And lastly, within a fibre itself, there is a great variability in the properties along its length.

The existence of this variability has, therefore, to be taken into account in the determination of any cotton fibre property. There is, then, the problem of measurement of this variability and its analysis, without which it would be difficult to say, for example, if a cotton is superior to another in respect of any fibre property. Also, the results of tests done on cotton would require to be expressed satisfactorily, if proper conclusions are to be arrived at.

TABLE 8. FIBRE PROPERTIES AND SPINNING VALUES OF STANDARD INDIAN COTTONS, 1955-56

Cotton	Botanical species	Fibre length (mm.)	Fibre length irregularity (per cent.)	Fibre weight per cm. (10^{-6} gms.)	Fibre strength (gms.)	Intrinsic strength*	Maturity (per cent.) M - H - I†	Blow-room loss (per cent.)	Card loss (per cent.)	Highest standard count
Jarila	*G. arboreum*	21·3	21·4	1·63	4·22	2·59	62 - 8 - 30	11·2	6·0	26
197-3 (Virnar)	,,	22·6	18·5	1·96	4·74	2·42	64 - 8 - 28	10·6	6·9	27
H. 420	,,	22·6	12·8	2·43	5·56	2·27	72 - 8 - 20	5·2	4·4	27
Gaorani 6	,,	21·5	12·9	1·97	5·50	2·79	77 - 6 - 17	3·4	4·0	31
Gaorani 12	,,	22·0	14·9	1·72	4·66	2·71	70 - 7 - 23	4·0	4·4	36
Karunganni 2	,,	21·8	20·7	2·22	5·43	2·45	74 - 5 - 21	6·8	5·2	26
Karunganni 5	,,	22·4	21·3	2·11	5·24	2·48	71 - 9 - 20	6·2	4·8	28
Nandyal 14	,,	22·2	15·6	2·07	6·05	2·92	73 - 7 - 20	9·1	4·8	29
Vijay	*G. herbaceum*	22·7	14·0	1·83	5·61	3·07	66 - 9 - 25	3·5	4·2	38
Surat 1027 A L. F.	,,	24·6	16·6	2·20	5·54	2·52	64 - 8 - 28	5·8	4·4	31
Vijalpa (2087)	,,	24·0	18·3	1·80	4·70	2·61	63 - 7 - 30	4·0	4·5	37
Kalyan	,,	21·2	17·1	1·86	3·60	1·94	46 - 13 - 41	10·6	5·4	25
Westerns 1 (H.1)	,,	21·8	12·9	1·95	3·72	1·91	55 - 11 - 34	5·5	5·5	32
Jayadhar	A hybrid	22·4	16·8	2·02	4·04	2·00	66 - 11 - 23	4·0	4·0	36
Laxmi (9-3)	*G. hirsutum*	22·7	21·6	1·31	3·02	2·44	34 - 11 - 55	5·6	6·5	46
L. S. S.	,,	22·0	19·0	1·72	4·00	2·33	62 - 10 - 28	9·2	5·6	29
320F	,,	23·1	19·3	1·77	3·85	2·18	62 - 8 - 30	9·8	6·2	34
Buri 0394	,,	24·0	18·7	1·82	4·08	2·24	60 - 12 - 28	5·6	4·9	37
Parbhani American 1	,,	23·1	26·1	1·71	3·30	1·93	45 - 16 - 39	5·4	6·2	30
Cambodia Co.2 (440)	,,	22·5	20·8	1·66	3·49	2·10	53 - 11 - 36	5·3	5·2	30
Madras Uganda 2 (Summer crop)	,,	23·6	27·5	1·35	3·30	2·44	43 - 13 - 44	7·4	6·0	41
Madras Uganda 1 (Winter crop)	,,	21·8	20·7	2·22	5·43	2·45	74 - 5 - 21	6·8	5·2	26

* Intrinsic strength = Fibre strength (gms.) ÷ Fibre weight per cm. (10^{-6} gms.).

† M = Mature fibres, H = Half mature fibres, I = Immature fibres.

Here comes the usefulness of statistics. The methods of statistics assist one, where the variations observed cannot be controlled, to deal with the data in a manner which will provide the maximum amount of reliable information. Assuming that the testing is accurate and reliable, these methods enable conclusions to be drawn with the minimum of testing, and indicate the degree of reliability of conclusions so drawn.

It is not proposed, in this chapter, to elaborate on all the applications of statistics to cotton technology, but to familiarize the readers with a few common statistical terms which are necessary to understand the significance of the test data obtained in any investigation carried out on such a highly variable material as cotton, and to give a few simple examples of their application. For a fuller account of these methods, readers should refer to books on statistics.

EXPLANATION OF SOME STATISTICAL TERMS

Frequency Distribution. One of the main objects of statistical methods is the description of a mass of observations, called the population, in terms which will make their significance easily understood. If there are large differences in the experimental values themselves, those that differ very slightly from one another may be grouped together in a class interval, and all the values in the group may be treated as equal, the mid point of the class interval being taken as the class value. The data may, thus, be divided into a convenient number of class intervals and the number of observations included in each group shown against them. Such a table, showing the frequency distribution of the data, is called a frequency table. Thus, if there are 3,000 values of fibre convolutions ranging from 15 to 224 per fibre, the table below would give their frequency distribution.

Class Interval	Class Value	Frequency
	(x)	(f)
15— 29	22	16
30— 44	37	192
45— 59	52	379
60— 74	67	462
75— 89	82	520
90—104	97	527
105—119	112	390
120—134	127	273
135—149	142	157
150—164	157	52
165—179	172	18
180—194	187	11
195—209	202	2
210—224	217	1
	Total	3,000

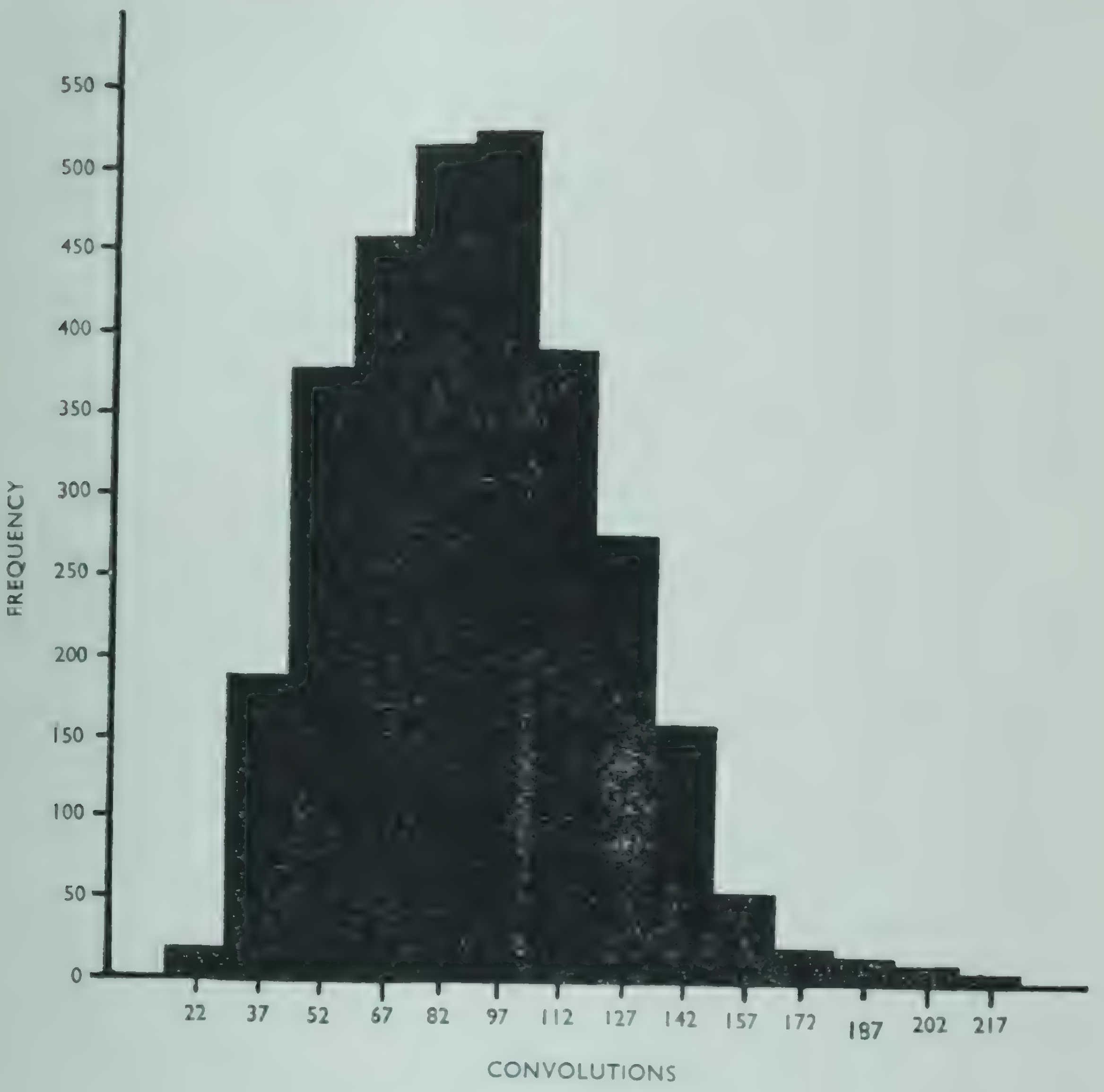

Fig. 15. Histogram

The form of the frequency distribution may be readily discerned, if it is represented diagrammatically. A simple method of showing the frequency distribution is by means of what is called a *histogram* (Fig. 15), which is constructed by drawing for each class interval a column, whose height is proportional to the corresponding frequency. We, then, obtain a number of rectangles of equal base but varying altitude, placed side by side. A more useful form of frequency diagram for comparative purposes is the *frequency polygon* (Fig. 16), which can be drawn by joining the mid-points of the tops of the rectangles of the histogram. If the class intervals become extremely small and the number of observations increases correspondingly, the frequency polygon would merge into a smooth curve, called the *frequency curve* (Fig. 16). In fact, however, the number of observations cannot be increased indefinitely and the frequency polygon never becomes a smooth curve. But, the observed values generally tend to give a frequency curve. Hence, the smooth curve that can be drawn to give the 'best fit' to the observed frequency distribution is taken as the theoretical frequency curve, which the frequency polygon would tend to approach.

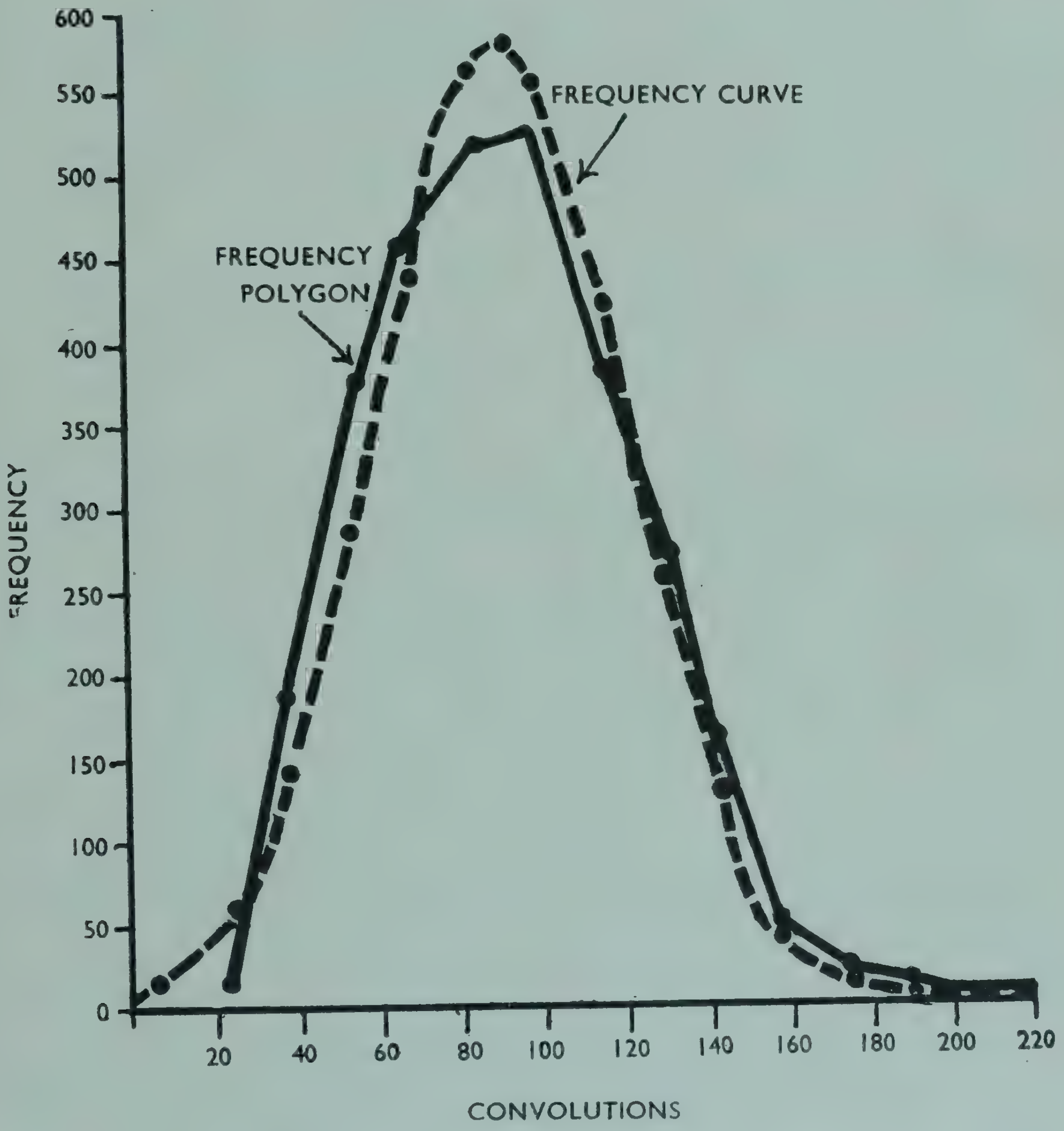

Fig. 16. Frequency Polygon and Frequency Curve

Mere representation of the data in the form of a diagram is not sufficient, as diagrams by themselves prove nothing. It is, therefore, necessary to characterise them by means of simple arithmetical measures. As can be seen from the histogram or the frequency curve, there is a tendency for the results to be concentrated about a central value, whose measures must be determined.

Measures of Central Value. The central value or the average is the most representative of the series, and lies somewhere in the centre of the series. There are three widely used measures of this value, namely, the *arithmetic mean*, the *median* and the *mode*.

Mean : The mean is the arithmetic average of all the observations, and is obtained by dividing the sum of all the values by the total number of values. It is the most probable value of the unknown, if the distribution of the values is symmetrical. It is also the most useful of all the measures of central value.

The mean is usually denoted by the symbol μ, and $\mu = \frac{\Sigma x}{N}$, where Σ represents the summation of all the N values of x in the series. Where the observations are expressed as a frequency distribution, the mean, μ, is obtained by the formula, $\mu = \frac{\Sigma f.x}{N}$, where f is the class frequency and x the class value.

Median : The median is the middle value of the series, when the values are arranged in order of magnitude, and hence, half the number of observations lie above it and half below it.

Mode : The mode is that value of the observations, which occurs most frequently ; it is, therefore, the x-value at which the frequency curve is at its highest point. In a frequency distribution, the mode lies in the class having the highest number of values. An approximate value of the mode can be obtained from the formula, $\text{Mode} = \text{Mean} - 3(\text{Mean} - \text{Median})$. In the case of a symmetrical curve, the mean, the median and the mode are identical.

If no more than the central value is calculated, a good deal of useful information would be lost. The variation about this central value is important and must be determined by proper measures.

Measures of Dispersion or Variability. A measure of variability shows how far the individual observations are scattered or spread on either side of the mean. The *range* and the *standard deviation* are the measures generally used for the determination of dispersion, the latter being the most important of all.

The range is the difference between the highest and lowest values of a variable. Though it is the simplest of all the measures of dispersion, it suffers from the defect that it solely depends on the extreme values and does not give any idea of the distribution of the intermediate values.

The standard deviation is a measure of dispersion based on all the observations, and is defined as the root mean square deviation from the mean. It is obtained by squaring the deviations of the individual values from the mean, and determining the square root of the mean of the squared deviations. Thus, $\sigma = \sqrt{\frac{\Sigma d^2}{N}}$, where σ is the standard deviation and d the deviation of the individual value from the mean. When the data are grouped in the form of a frequency distribution, the formula becomes $\sigma = \sqrt{\frac{\Sigma f. d^2}{N}}$. But here, a correction factor, called Sheppard's Correction, has to be applied to compensate for the error introduced by grouping the observations into classes and basing the conclusions on the values of class centres, and, therefore, $\sigma = \sqrt{\frac{\Sigma f. d^2}{N} - \frac{1}{12} I^2}$, where $\frac{1}{12} I^2$ is the correction factor and I the class interval.

The above measures of variability are absolute and in the same units as the observations.

A measure of variation, which is independent of the unit of measurement and, hence, is useful for comparing different populations, is provided by the *coefficient of variation*, which is standard deviation expressed as a percentage of the mean. That is, $C.V. = \frac{\sigma}{\mu} \times 100$.

Normal Distribution. It has been mentioned earlier that a frequency curve can be fitted to an observed frequency distribution. There are many types of frequency curve. A very important type, both in theory and practice, is the *normal probability curve*, or simply the normal curve, which is symmetrical and represented by the mathematical equation,

$$y = \frac{N}{\sigma\sqrt{2\pi}} \cdot e^{-\frac{x^2}{2\sigma^2}},$$

where y is the ordinate representing the frequency of occurrence of a given value, x the abscissa expressed as a deviation from the mean, N the total number of observations, σ the standard deviation and e the exponential base(=2·718). The normal curve is an error curve and, as such, the frequency distribution of a series of experimental observations may be represented by it, if the probability of a random value of the series being greater than the mean is equal to the probability of its being less than the mean.

The normal curve is determined by the mean and standard deviation of the population. Nearly 2/3rds of the total number of observations lies within the range of $\mu \pm \sigma$ and 95 per cent. within $\mu \pm 2\sigma$, and only about 3 of every 1,000 values fall outside the limits $\mu \pm 3\sigma$ (Fig.17). For a normal curve, the total area covered within these limits, depends on the ratio, $\frac{(x-\mu)}{\sigma} = \omega$, which is called the *normal deviate.*

A table, showing the proportions of observations lying below the successive values of the variate, is known as the *probability integral table,* which is usually given in books on statistics.

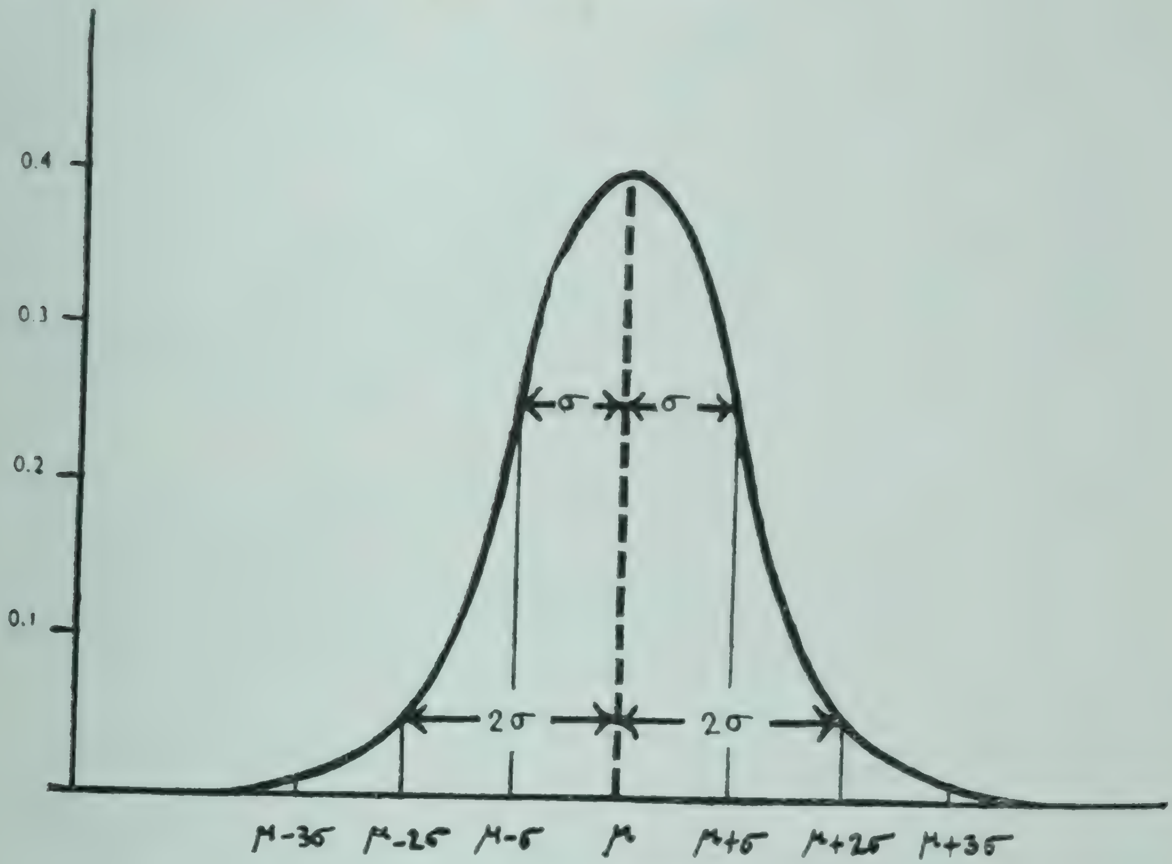

Fig. 17. Normal Distribution

Standard Error. So far, the populations as a whole have been taken into consideration. In actual practice, however, it is rarely possible to make observations on all the individuals comprising the populations, which are many a time hypothetical. It becomes necessary, therefore, to obtain information about the population from a portion thereof, which is called the *sample*, and which represents the whole population. There are many methods of selecting the sample, but the simplest and most commonly used is the method of *random sampling*, in which the sample is drawn at random without any bias and every portion of the bulk stands an equal chance of being selected as the representative sample. It is a property of random sampling that the mean of the means of samples tends to approach the population value. Another important property of random samples is that the distribution of their means will be normal, if the parent population is normally distributed, or even approximately so.

The means of samples of the same size cluster more and more near the mean of the population as the sample size increases. The variability of the means of random samples of a given size is related to the variability of the parent population by the formula, $S.E. = \frac{\sigma}{\sqrt{n}}$, where σ is the standard deviation of the parent population, n the number of individuals in the sample, and S.E. the standard deviation of the means of samples, which is commonly known as the *standard error.* The square of the standard error is called the *sampling variance* of the mean.

The standard error of the sum or difference of means of two samples is the same, and is given by the formula:

$$\text{S.E.}_{(\bar{x}_1 + x_2)} = \sigma \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}$$

$$= \text{S.E.}_{(\bar{x}_1 - \bar{x}_2)},$$

where $\bar{x}_1$ and $\bar{x}_2$ are the means of two samples, and n_1 and n_2 are the sample sizes.

The standard deviation of the population, σ, is estimated from the sample by the following formula for samples, namely,

$$S = \sqrt{\frac{\Sigma\,(x - \bar{x})^2}{n-1}}$$

where S is an estimate of σ, $(x - x)$ the deviation from the mean, and n the sample size. The denominator, (n-1), is called the *degrees of freedom,* which corresponds to the number of independent deviations available from the data, and can be obtained by subtracting the number of constants that are to be calculated from the number of values in the data. The square of the standard deviation is known as *variance.*

Tests of Significance of Means and Their Differences. Many of the scientific investigations start with certain working hypotheses which are then tested experimentally. The hypotheses are taken to hold good till the experiments disprove them. This is the general method by which many statistical inferences are made. It is not possible to say with certainty whether a sample, like the one observed, has come from the postulated hypothetical population of certain characteristics ; only a probability that it could have come from that population can be assumed. If the probability is low, the hypothesis is rejected ; if it is high, the hypothesis holds good, and the deviation of the sample from the postulated population is attributed to errors of sampling.

The probability of such a random deviation exceeding any given value is called the *level of significance* of the deviation, and is often expressed as a percentage. A large deviation that is on a sufficiently low probability level to lead to a rejection of the hypothesis regarding the population, is said to be *statistically significant,* and the mean of the sample is said to be significantly different from that of the population. The selection of a probability level is a matter of choice, depending on the desired level of accuracy of the experimental value, but usually a probability of 0.05 is taken as the critical level of significance, a more stringent level being the probability of 0.01.

The statistical procedure of deciding whether the hypothesis should be accepted or rejected is called the *test of significance.* It will be seen from the probability integral table, given in any standard book of statistics, that a deviation of twice the standard error corresponds roughly to a probability level of 0.05, and, therefore, a deviation of a sample mean of twice the standard error from an assumed population value lies on 0.05, or 5 per cent., level of significance, and a deviation larger than this is statistically significant.

The most common situation is one, in which the observer wishes to know if the differences are real or due to random sampling. In other words, it is desired to test whether the two samples can be regarded as having been drawn from the same normal population. It will be recalled that the standard error of the difference of means of two samples is $\sigma.\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$ whose estimate is given by $S.\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$, where $S=\sqrt{\frac{(n_1-1)S_1^2+(n_2-1)S_2^2}{n_1+n_2-2}}$, S_1 and S_2 standing for the standard deviations of the two samples, respectively. Then, the ratio, $\frac{\text{difference between the means}}{\text{S. E. of difference}}$, is taken as the normal deviate, whose value is referred to in the table of normal probability integral to determine the probability level.

The above method is followed only if the samples are large enough to be taken to provide an accurate estimate of the population values, and are independent. In practice, however, σ is usually not known, and the sample estimate, S, has to be substituted. With large samples, S and σ are sufficiently alike to make this method reasonably accurate. But, it happens, not infrequently, that we have to compare the means obtained from samples consisting of only a few observations. In such cases, when the samples are small, S is not a sufficiently accurate estimate of σ, and some allowance must be made for the error involved in using S instead of σ. The distribution of the quantity, $\frac{\text{difference of means}}{\text{S. E. of difference}}$, deviates considerably from normality, when the population variance is estimated from a small sample, and is denoted by *t*, whose values, required for significance at various levels of probability and for different degrees of freedom, are given in tables, called the *t* tables, in any standard book on statistics. If $\bar{x}$ is the mean of a sample of size n, and S the standard deviation estimated from the sample, and if we are testing the deviation of $\bar{x}$ from a hypothetical value μ, then,

$$t = \frac{(\bar{x}-\mu)}{S\sqrt{n}}$$

with (n-1) degrees of freedom. If we want to test the significance of difference between the means of two independent samples, then

$$t = \frac{\bar{x}_1 - \bar{x}_2}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} = \frac{\bar{x}_1 - \bar{x}_2}{S} \cdot \sqrt{\frac{n_1 n_2}{n_1 + n_2}}$$

with (n_1+n_2-2) degrees of freedom. When the samples are of equal size of n, $t = \frac{x_1 - x_2}{S} \cdot \sqrt{\frac{n}{2}}$, with $2(n-1)$ degrees of freedom. (In these two formulae, $S = \sqrt{\frac{(n_1-1)\,S_1^2 + (n_2-1)\,S_2^2}{n_1 + n_2 - 2}}$, as already mentioned.) If the calculated value for t is lower than the one given in the table at the desired probability level, then the difference is not significant; if it is higher, it is significant.

Another method of testing the significance between the means is by the F-test, which can be applied when the total variation is analysed into components assignable to different causes and entered in the form of a table, called the *analysis of variance table*. Reference may be made to books on statistics for this test.

Correlation and Regression. So far, the variation in only a single variable has been dealt with. We shall now briefly consider the simultaneous variation of two variables. It is often observed that changes in one variable are accompanied by changes in another, and that a definite relationship exists between the two. There is, then, said to be a *correlation* between the two variables. When the changes are such that an increase in one variable produces an increase in the other, the two variables are said to be positively correlated. On the other hand, if an increase in one variable should cause a decrease in the other, they are negatively correlated. Just as we have the frequency table for a single variable, we can have a correlation table for the simultaneous distribution of two variables.

The magnitude of the correlation is indicated by a coefficient, called the *correlation coefficient*, which is denoted by the symbol ρ, and calculated from the formula, $\rho = \frac{\sigma_{xy}}{\sigma_x . \sigma_y}$, where $\sigma_{xy} = \frac{\Sigma f\,(x-\bar{x})(y-\bar{y})}{N}$,

and σ_x and σ_y are the standard deviations of x and y, respectively. The estimate of ρ, calculated from a sample, is denoted by r, and since σ_{xy} can be both positive and negative, and cannot exceed the product $\sigma_x . \sigma_y$, the correlation coefficient, necessarily, varies between +1 and –1.

The correlation coefficient is also a numerical character of the population, just as the mean and the standard deviation are. It can be estimated from a sample of the bivariate population, but this estimate is subject to sampling errors. The standard error of r, the estimate from n pairs of values of ρ, is given by $\sigma_r = \frac{1-\rho^2}{\sqrt{n-1}}$. The significance of r is tested by using the formula,

$$t = \frac{r}{\sqrt{1-r^2}} \cdot \sqrt{n-2}, \text{ with } (n-2) \text{ degrees of freedom.}$$

An easier way of treating the simultaneous variation of two variables is to draw lines relating these variables. These are called the *regression lines*, and can be represented by a mathematical equation, known as the *regression equation*. If the regression of the variable y on the variable x is to be determined, then y is called the dependent variate, and x the independent variate. The *linear regression* is represented by a straight line and can be mathematically written as $Y = a + b.x$, where Y is the expected value corresponding to any given value of x, and a & b are constants so chosen that the quantity $\Sigma\,(y - Y)^2$ is minimum, y being the observed value of the dependent variate. This method of fitting the line is known as the *method of least squares*. The constants a and b are calculated from the formulae, $a = \bar{y} - b.\bar{x}$, and $b = \frac{\Sigma(y-\bar{y})\ (x-\bar{x})}{\Sigma(x-\bar{x})^2}$, where, $\bar{y}$ and $\bar{x}$ are the means of y-values and x-values, respectively. A similar line may be obtained by giving X in terms of y. The equations of the two lines can be transformed to the following form :

$$(Y - \bar{y}) = r.\ \frac{\sigma_y}{\sigma_x} \cdot (x - x),$$

$$\text{and } (X - \bar{x}) = r.\ \frac{\sigma_x}{\sigma_y} \cdot (y - \bar{y})$$

These are the regression lines, and the constants, $r\,\frac{\sigma_y}{\sigma_x}$ and $r\,\frac{\sigma_x}{\sigma_y}$ are called the *regression coefficients*. From this it follows that the sample estimate of the correlation coefficient, $r = \sqrt{\text{product of the regression coefficients}}$.

When more than two variables are being studied, other constants, like the *partial correlation coefficient* and the *multiple correlation coefficient*, are also used. The *partial correlation coefficient* denotes the strength of association between one dependent variable and another independent variable, after making allowance for their association with the other variables involved. The *multible correlation coefficient* gives the strength of association between one dependent variable and all the independant variables taken together.

PRACTICAL APPLICATIONS OF SIMPLE STATISTICAL METHODS IN COTTON TECHNOLOGY

The foregoing describes, briefly, some of the statistical constants, which are most commonly used in cotton technology. A more rigorous analysis of the data will be necessary when other statistical measures, not mentioned here, will have to be applied. The actual computation of these constants and the methods of their application are given in any of the standard books on statistics. It is proposed to give here only a few applications in the study of the fibre properties.

As an illustration of the measures of the central value and dispersion, let us take the following frequency distribution of single fibre strength for a cotton.

Strength (gms.) (x)	Number of fibres (f)
3	8
4	5
5	6
6	12
7	16
8	22
9	18
10	10
11	15
12	8
13	5
14	3
15	2
Total	130

$$\text{Mean, } \mu = \frac{\Sigma\, f.x}{N} = 8.42 \text{ gm.}$$

Median = 8.32 gm.
Mode = Mean – 3 (Mean–Median) = 8.12 gm.

$$S = \sqrt{\frac{\Sigma(x - \bar{x})^2}{n-1}} = 2.82 \text{ gm.}$$

$$\text{C.V. } (\%) = \frac{S \times 100}{\mu} = 33.49$$

Since a normal distribution is symmetrical, the mean, median and mode will all coincide. When the curve is not symmetrical, it is said to be of a *skew type*. The further apart these three values, viz., mean, median, and mode, become, the more is the departure from symmetry, the difference between the mean and the mode being the greatest. Therefore, this difference becomes a measure of skewness. But, in order to have an index for comparative purposes, it is obtained by the formula,

$$\text{Skewness } (S_k) = \frac{\text{mean} - \text{mode}}{\text{standard deviation}}.$$

In our example, therefore, skewness $= \dfrac{8.42 - 8.12}{2.82} = +\,0.106.$

The frequency curves for the different fibre properties of cotton have been classified as follows:

Fibre length
Convolutions } — Moderately symmetrical and nearly normal.
Fibre width — Symmetrical, practically normal.
Fibre strength — Moderately asymmetrical.
Fibre rigidity — Extremely asymmetrical.

This gives us an idea of the nature of the distribution of some of the fibre properties. Similarly, Table 9 shows the measures of the central value and dispersion for some of the fibre properties of cotton.

TABLE 9. MEASURES OF CENTRAL VALUE AND DISPERSION FOR SOME FIBRE PROPERTIES OF COTTON

	Number of tests	Mean	Median	Mode	Standard deviation	Coefficient of variation
Fibre length (cm.)	4,000	2·33	2·35	2·380	0·491	21·00
Fibre width (10^{-5} cm.)	3,000	179·88	179·64	178·800	19·920	11·05
Fibre strength (gms.)	3,000	3·91	3·50	2·255	2·357	60·40
Fibre rigidity (10^{-2} dynes/cm^2)	4,000	2·47	14·60	—	2·936	118·80
Convolutions (per fibre)	3,000	88·78	87·51	83·830	30·900	34·80

The t-test for the determination of the significance of the difference between the means is one of the tests, that is frequently applied in cotton research. For instance, the characters of the fibres drawn from different regions of the seed were studied, and it was observed that the fibre weight per unit length of fibres at the apical region differed from that of fibres at the basal region. In order to find out whether this difference was *real*, or due to *random sampling* only, the t-test was applied to the data given in Table 10.

TABLE 10. SIGNIFICANCE OF DIFFERENCE IN FIBRE WEIGHT PER UNIT LENGTH OF FIBRES IN APICAL AND BASAL REGIONS OF SEED

Cotton	Significance of means					
	Apical region Mean (10^{-6} gm./cm.)	Basal region Mean (10^{-6} gm./cm.)	n	t	t for p=0·01	Remarks
Nandyal 14	2·31	1·96	36	9·00	2·72	Significant
C. A. 9 (1928-29)	2·01	1·69	28	8·19	2·76	"
C. A. 9 (1929-30)	1·97	1·70	33	12·41	2·73	"

Applying the formula, $t = \frac{\bar{x}_1 - \bar{x}_2}{S}\sqrt{\frac{n}{2}}$, where $\bar{x}_1$ is the mean fibre weight per unit length of apical end fibres, $\bar{x}_2$ the mean fibre weight per unit length of basal end fibres, n the number of fibres tested in each region, and $S = \sqrt{\frac{S_1^2 + S_2^2}{2}}$, S_1 and S_2 being the standard deviations for the apical end and basal end fibres, a value of 9 for t was obtained in the case of Nandyal 14 cotton. This value is higher than the value of t at probability level of 0.01 given in the t-table. Hence, the difference between the fibre weights per unit length of the apical and basal regions, is significant, and is not due to random sampling. Similarly, this difference is significant in the other cottons also. It was, therefore, concluded that the mean fibre weight per unit length, in the case of these cottons, is significantly greater for the apex fibres than for the base fibres.

The t-test can be applied in a slightly different way also. Since $t = \frac{\bar{x}_1 - \bar{x}_2}{S}\sqrt{\frac{n}{2}}$, $\bar{x}_1 - \bar{x}_2 = \frac{t.S.\sqrt{2}}{\sqrt{n}}$ = C.D. or the *critical difference.*

So, if the difference between any two means is more than the critical difference for a required level of significance, then it becomes significant and real. Otherwise, the observed difference is only due to *random sampling.*

The analysis of variance is a statistical method, which is essential in almost all investigations on cotton. As explained earlier, this method breaks down the causes of variation into its components. In an investigation on the moisture relations of Indian cottons, for example, the moisture absorption of different botanical species was studied. The cottons included in the investigation were divided into four groups: (*i*) *G. hirsutum;* (*ii*) *G. herbaceum;* (*iii*) *G. arboreum*, long-staple varieties; and (*iv*) *G. arboreum*, short-staple varieties. The moisture absorbed at each of the five humidities, namely, 50, 57, 68, 77, and 84 per cent. relative humidity, by eight varieties of cotton belonging to these four groups, was determined by two observers. The variations were split up by subjecting the data to analysis of variance, as in Table 11.

TABLE 11. ANALYSIS OF VARIANCE

Source of variance	Degrees of freedom	Sum of squares	Mean square
Humidity	4	199·4914	49·8729 **
Groups	3	0·8977	0·2992 **
Varieties within groups	4	3·3906	0·8476 **
Humidity × groups	12	0·4053	0·0338 †
Humidity × varieties within groups	16	0·9875	0·0617 †
Duplicate	1	0·0058	0·0058 †
Experimental error	39	2·3309	0·05977†
Total	79	207·5092	

** Highly significant (P = 0·01 level of significance). †Not significant.

Applying the F-test for the difference between humidities, we have, $F = \frac{49.8729}{0.05977} = 831.2$, which is found to be much greater than the value of 3.83 for F, for 4 and 39 degrees of freedom, from the F-table given in any book. Therefore, the variation due to humidity is highly significant. Similarly, the variations due to the others were tested for significance.

This table helps us to understand the effect of different factors on the absorption of moisture. It will be noticed that the effect of relative humidity is highly significant. Both the interactions do not have any effect. The variance due to 'duplicate' is very small, showing thereby, that the personal error of observations is negligible. On the other hand, the variances due to groups and varieties within groups are highly significant.

The application of the correlation and regression methods is again very frequent. The object of one of the investigations was to know whether wax, which is one of the non-cellulosic constituents of cotton, is confined only to the surface of the fibre. The correlation between the wax content of cotton and its surface area per unit weight was determined, the correlation coefficient being + 0.87. A regression equation, $W = 0.3402\ S - 0.4081$, where W is the wax content and S the surface area per unit weight, was worked out and the regression line fitted (Fig. 18). The straight line relationship and the high correlation between the wax content and the surface area, therefore, suggest that wax occurs mainly on the surface of the cotton fibre.

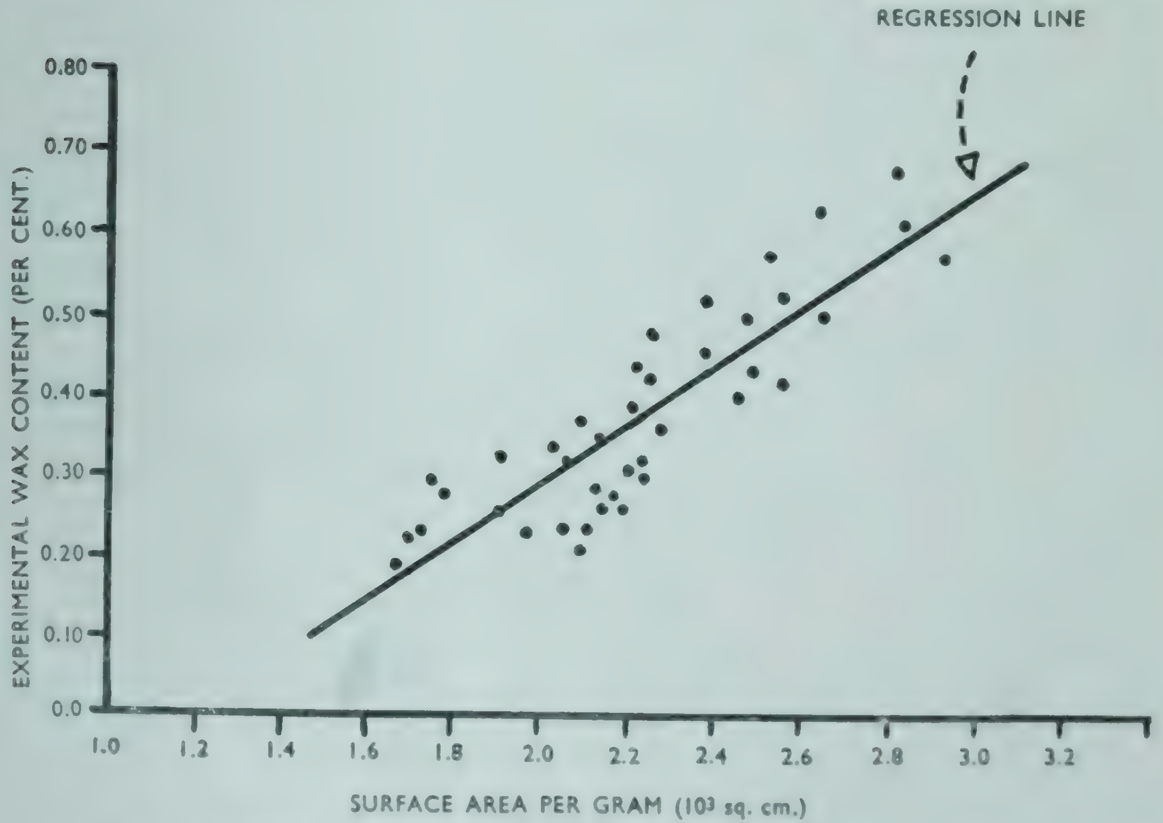

Fig. 18. Relation between the Wax Content and Surface Area of Cotton Fibre

One of the many problems in cotton technology, on which several workers have concentrated their attention, is the prediction of the spinning value of a cotton from its fibre properties. For this purpose, it would be necessary to work out a reliable regression equation between the spinning value, say, as determined by the highest standard count, and the measurable fibre properties likely to influence the spinning value. In one investigation, where the cottons were classified according to the botanical species to which they belonged, the regression equations for the *G. herbaceum* varieties were worked out by applying the formula for multiple regression equation, $X_1 = a + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + \ldots\ldots$ where

X_1 = Highest standard count,
X_2 = Mean fibre length (inch),
X_3 = Fibre weight per inch (10^{-6} oz.),
X_4 = Swollen fibre diameter (10^{-3} inch), and
X_5 = Fibre length irregularity percentage.

These regression equations are given in Table 12. Now, the *standard error of estimate* indicates the closeness with which values estimated from a regression equation may be expected to approximate the true, but unknown, values. It shows the reliability of an estimated value based on previously observed relations, and is equal to the standard deviation of the residual differences between the observed values and those estimated from the regression equation. It is, thus, given by the formula, $E^2 = \frac{n.\ \sigma_r^2}{n-2}$, where E is the *standard error of estimate*, and σ_r the standard deviation of the residuals. Applying this formula in our example, it is seen that the standard error of estimate of the spinning value from equation (1) in Table 12, where only the fibre length and fibre weight per unit length are considered, is 4·7 counts. This error reduces to 4·1, when the swollen fibre diameter is included as in the equation (2), or even when the swollen fibre diameter and fibre

TABLE 12. REGRESSION EQUATIONS BETWEEN SPINNING VALUE AND FIBRE PROPERTIES OF COTTONS BELONGING TO *G. herbaceum* SPECIES

Regression equations	Standard error of estimate (counts)
1. $X_1 = 17{\cdot}5 + 56{\cdot}3\,X_2 - 197{\cdot}4\,X_3$	4·7
2. $X_1 = 49{\cdot}3 + 60{\cdot}0\,X_2 - 117{\cdot}8\,X_3 - 46{\cdot}4\,X_4$	4·1
3. $X_1 = 46{\cdot}9 + 62{\cdot}7\,X_2 - 110{\cdot}7\,X_3 - 44{\cdot}8\,X_4 - 0{\cdot}231\,X_5$	4·1

length irregularity are taken into consideration as in the equation (3). This means that the estimation of the spinning value is not much improved by taking more fibre properties than the fibre length and fibre weight per unit length.

The correlation coefficients between the highest standard count and the fibre length, fibre weight per unit length, swollen fibre diameter and fibre length irregularity, are given in Table 13. In order to find out the strength of association between the spinning value and the fibre properties taken together at a time, the multiple correlation coefficients, $R_{1.234...}$, were calculated by using the formula, $R_{1.234...} = \frac{\sigma_{1(234...)}}{\sigma_1}$. The strength of association between the spinning value and a particular fibre property, after allowing for the influence of other fibre characters, was determined by calculating the partial correlation coefficients by applying the formula,

$$r^2_{12 \cdot 34 \cdots} = \frac{(1 - R^2_{1 \cdot 34 \cdots}) - (1 - R^2_{1 \cdot 234 \cdots})}{(1 - R^2_{1 \cdot 34 \cdots})}$$

TABLE 13. CORRELATION COEFFICIENTS BETWEEN SPINNING VALUE AND FIBRE PROPERTIES OF COTTONS BELONGING TO *G. herbaceum* SPECIES

Simple	Partial	Multiple
$r_{12} = + 0 \cdot 61$ **	$r_{12 \cdot 345} = + 0 \cdot 65$**	$R_{1 \cdot 23} = 0 \cdot 823$ **
$r_{13} = - 0 \cdot 72$ **	$r_{13 \cdot 245} = - 0 \cdot 44$**	$R_{1 \cdot 235} = 0 \cdot 830$ **
$r_{14} = - 0 \cdot 64$ **	$r_{14 \cdot 235} = - 0 \cdot 49$**	$R_{1 \cdot 234} = 0 \cdot 872$ **
$r_{15} = - 0 \cdot 21$	$r_{15 \cdot 234} = - 0 \cdot 14$	$R_{1 \cdot 2345} = 0 \cdot 874$ **

* Significant – 0·05 level. ** Highly significant – 0·01 level.

It will, thus, be seen that, even when the other fibre properties are eliminated, there is a strong association between the spinning value and each of the three fibre characters, viz., length, weight per inch and swollen fibre diameter. The fibre length irregularity percentage does not seem to have any effect on the spinning value at all. The partial regression coefficients for the fibre weight per inch, as can be seen from the regression equations, are all high, showing thereby the importance of fineness for this class of cottons.

In addition to the linear relationships, examples of which are given above, there are cases where the relation between the variates is not so simple. *Quadratic* and *cubic* regression equations, which represent different shapes of curve, are, therefore, sometimes used to denote the trend in the observations. For instance, in the work on moisture relations of Indian cottons, it was desired to find an equation for reducing the weight of a sample at any humidity to that at a standard relative humidity in the case of cottons, where it was not possible to know whether they were in a wetter or drier atmosphere than the present. A cubic equation, viz., $W_h = 1124.9489 - 1.686848\ h + 0.03740042\ h^2 - 0.000142368\ h^3$, where W_h = weight of cotton (gms.) at a relative humidity h per cent., was fitted to the data obtained, and it gave a good fit.

Number of Tests Necessary, or Size of a Sample. For the determination of any fibre property, it is necessary to work out the size of a satisfactory sample. The number of tests required for any specified accuracy, say, 5 per cent. on either side of the mean, at probability level 0.05, can be calculated from the formula, $n=\frac{(1\cdot96V)^2}{P^2}$, where n is the number of tests necessary to obtain a mean value, with P per cent. accuracy, V the coefficient of variation and 1.96 the factor for probability level 0.05. Some preliminary work will give an idea of the coefficient of variation, from which the number of tests necessary to estimate the mean to the desired accuracy, can be determined.

The degree of reliability of small samples for the determination of different fibre properties, is indicated in Table 14, which shows the total range, expressed as a percentage of the mean, for which the odds, that the mean of a random sample of the given size will lie therein, are as indicated.

TABLE 14. SAMPLE SIZES AND DEGREE OF THEIR RELIABILITY FOR DETERMINATION OF FIBRE PROPERTIES OF COTTON

Fibre property	Odds	Size of sample				
		200	300	400	500	600
Fibre length	20:1	18	16	13	11	9
Fibre width	20:1	4	2·7	2	—	—
Convolutions	20:1	30	24	20	19	18
Fibre strength	20:1	40	23	17	15	13
Fibre rigidity	5:1	—	60	55	48	44
Fibre maturity	20:1	14·1	11·5	10·0	8·9	8·2
Swollen fibre diameter	20:1	1·96	—	—	—	—

Thus, we see, for example, that in the case of fibre width, the odds are 20:1, that the mean of a random sample of 200 fibres will lie within a range of 4 per cent. of the mean value of fibre width; this is 2 per cent. on either side of the mean, since the distribution of values of fibre width is symmetrical.

In the selection of a certain size of the sample as a representative of the whole population, the degree of reliability of the results for that size and the practical difficulties involved in making a large number of tests have to be taken into consideration. Keeping these points in mind, the following have been considered as the minimum numbers of tests, which should be made in the determination of several fibre properties (Table 15).

TABLE 15. MINIMUM NUMBER OF TESTS NECESSARY FOR DETERMINATION OF FIBRE PROPERTIES OF COTTON

Fibre property	Number of fibres for representative sample	Total range (per cent. of mean) for which the odds are 20:1 that the random sample will lie therein
Figre length	500	11·00
Fibre width	300	2·70
Convolutions	500	19·00
Fibre rigidity	500	48·00 (odds 5:1)
Fibre maturity	500	8·90
Swollen fibre diameter	200	1·96

As can be seen from the foregoing, a brief survey of some of the most common applications of the statistical methods, with particular reference to cotton technology, has been made in this chapter. Those who are interested in the further study of statistics and its application to cotton and textile technology more seriously, may read standard books, the titles of some of which are given below for ready reference:

1. "Statistical Methods for Research Workers", Fisher, R. A., Oliver & Boyd, London.
2. "Methods of Statistics", Tippet, L. H. C., Williams & Norgate Ltd., London.
3. "Methods of Correlation Analysis", Ezekiel, M., John Wiley & Sons, Inc., New York.
4. "Design of Experiments", Fisher, R. A., Oliver & Boyd, London.
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7. "Statistical Methods in Research and Production", Davies, O. L., Imperial Chemical Industries Ltd., Oliver & Boyd, London.
8. "Applied General Statistics", Croxton, F. E. and Cowden, D. J., Prentice Hall, Inc., New York.
9. "Design and Analysis of Industrial Experiments", Davies, O. L., Imperial Chemical Industries Ltd., Oliver & Boyd, London.
10. "Statistical Methods for Agricultural Workers", Panse, V. G., and Sukhatme, P. V., Indian Council of Agricultural Research, New Delhi.
11. "Technological Applications of Statistics", Tippet, L. H. C., John Wiley & Sons, Inc., New York.
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CHAPTER II

GINNING AND PRESSING

INTRODUCTION

GINNING

Cotton picked from the plant is in the form of seed cotton (*kapas*), and before the fibres can be used for any purpose, they have to be separated from the seed. The process of separation is called 'ginning.' It is the first mechanical process to which cotton is subjected. As the fibres are fairly firmly attached to the surface of the seed, it requires a certain amount of force to detach them. Unless this force is tempered in some way, the fibres are likely to be torn irregularly and their texture impaired. Thus, ginning is not only an essential process in the utilisation of cotton, but also an important one, as any damage to the fibres at this stage cannot be rectified later. The efforts of plant breeders and growers to produce superior varieties of cotton are often nullifield by improper ginning. In their disregard for ginning, both the grower and the manufacturer are liable to sustain heavy losses.

Poor ginning may be due to some of the following causes (Willis, 1932): (*i*) excessive dampness or dryness of cotton during ginning; (*ii*) inefficient ginning machinery; (*iii*) improper machine setting and speeds; and (*iv*) inadequate cleaning of seed cotton before ginning. The gin-damaged lint usually consists of entangled and matted fibres, cut fibres, excessive foreign matter and motes, neps, hull pieces, etc. Such cotton not only produces excessive waste, but also presents considerable difficulties during processing, increases labour costs, produces weaker and less uniform yarns, and detracts from the appearance of the finished product.

PRESSING

Cotton is a bulky material and requires considerable space for storage and transport. In the early days, when production was small and was consumed locally, this question was not of any importance. However, when the textile industry developed on a huge scale, requiring large quantities of cotton to be transported not only from nearby areas but also from distant lands, and sometimes from overseas, the problem of handling, storage and transport became very important. Hence, cotton had to be packaged into suitable size and weight for convenient handling and minimising freight charges. For this purpose, it is normally pressed into a bale of rectangular shape of appropirate size and weight by means of pressing machines.

HISTORICAL BACKGROUND

The separation of cotton fibres from the seed has been achieved by various methods. During the earliest days, it was merely separated by hand (Brown, 1938; Watson, 1879). This was a very slow and laborious process, but may have suited those times when wants were few and leisure plenty. A woman, working for the whole day, could produce about a pound and a half of lint. The foot roller (Watson, 1879) (Fig. 19) appears to have taken the place of hand-ginning. Here, the ginning is accomplished by spreading the seed cotton on a flat smooth stone and rolling a cylindrical iron rod of about 18 inches over it by pushing it forward under pressure, in a rolling motion by the foot of the worker. Sometimes, the rod was shorter and slightly conical in shape, so that the motion was rendered circular over the stone. In both these cases, the effect is that under the combined influence of the rolling motion and the pressure exercised by the foot, the seed is squeezed and pushed away in front of the iron roller, leaving the clean cotton fibre behind it on the stone.

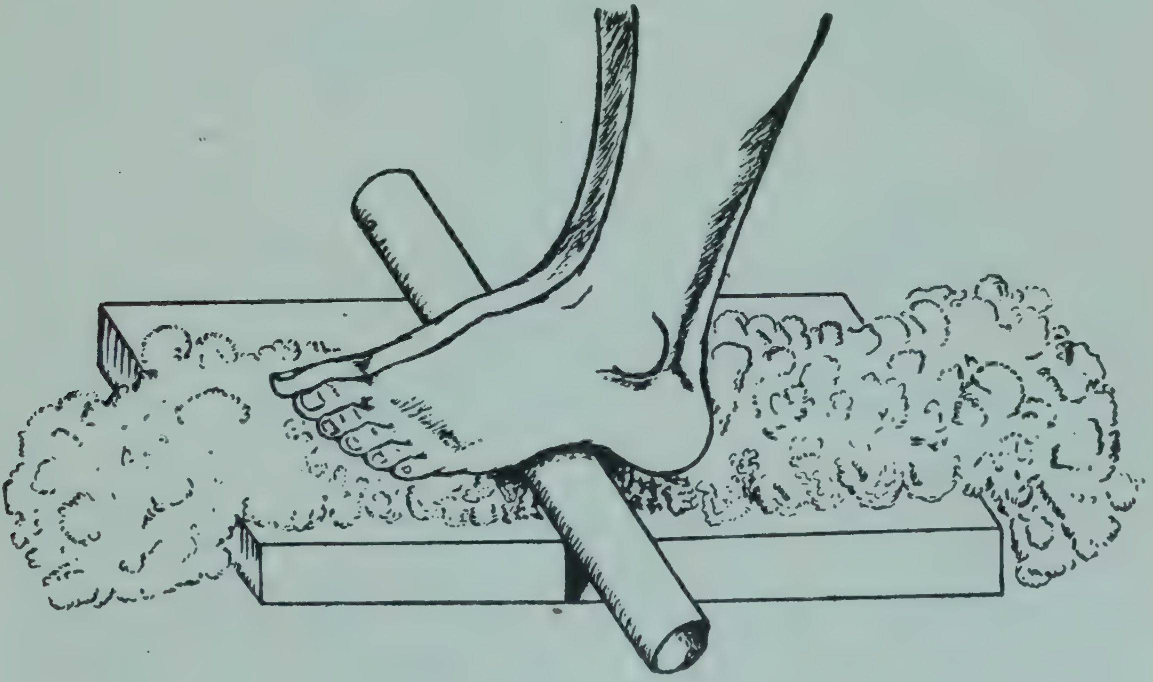


Fig. 19. Foot Roller

The *Charkha* gin (Fig. 20) is probably the earliest recorded ginning machine. It was used in India many centuries ago, and a greater part of Indian cottons was ginned by such machines even as late as at the close of the last century. Even at present, a great many of these gins are in use in the rural parts of the country. This gin consists of two upright pieces of wood (Brown, 1938; Watson, 1879), made secure at the base, between which two small, horizontal, parallel wooden rollers of like diameter, so adjusted that they touch one another, move in opposite directions by means of Archmidian screws. The seed cotton is fed between the rollers by hand and the lint caught between the rollers is drawn out and pulled from the seed, which is unable to pass between the rollers. This type of gin is best suited for cottons with clean, naked seeds like some of the tree cottons or those with slightly fuzzy but hardy seeds like *desi* varieties grown in India. The action in this gin is much less drastic than the foot roller. Yet, the pressure between the rollers sometimes squeezes the immature or weak seeds, especially in the case of American varieties of cotton, which are not as hardy as *desi* varieties (Watson, 1879). A woman working on this gin could produce some four to five pounds of lint per day.

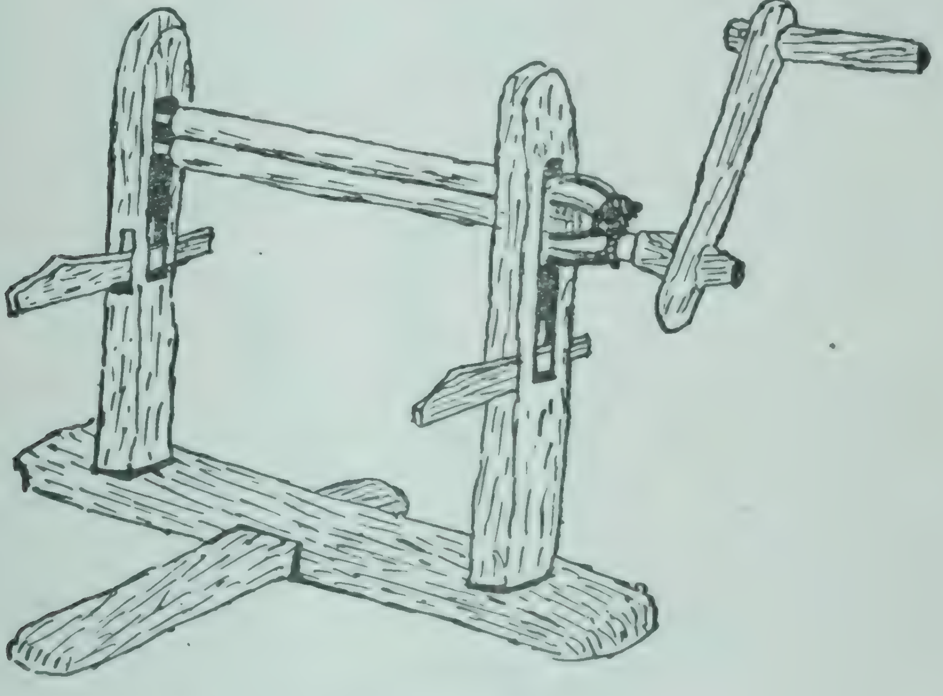


Fig. 20. *Charkha* Gin

The *Charkha* gin has been modified and improved in various ways and used all over the country in different forms (Watson, 1879). One of the two rollers has been replaced by an iron roller, and the other wooden roller increased in diameter. Further, instead of rotating the roller by hand, a foot pedal was often employed, thereby increasing the output of lint. Some of these types, called the *Bardoli* (Plate Va) and *Sabarmathi* gins, were very popular some years ago and are even now in use in several parts of the country.

The next improvement in the principle of ginning appears to be roller gin, in which the roller rotates pressing against a 'doctor' knife or a steel blade, whose edge is very close and parallel to the surface of the roller. The lint fibres, which are carried away by the roller, are pulled off from the seed, which cannot escape through this passage. However, the output of this type of gin is also very small.

The process of ginning by methods mentioned above is very slow and unsuitable when large quantities of lint are required. The inventions of Hargreaves, Arcwright, etc., in England between 1770 to 1785 revolutionised the cotton industry there and created immense demand for cotton all over the world. It became, therefore, absolutely necessary to obtain large quantities of cotton very quickly. Eli Witney of America (Brown, 1938), developed the model of one of the greatest inventions of the textile industry, namely, the saw gin, which he patented in 1794. It was a very small gin having a cylinder of 25 inches length and six inches diameter. Nevertheless, it gave 50 times as much lint as a man could do in the old-fashioned way. It consisted of a series of saws, forming the rotating cylinder to which cotton was fed through the wire grid, through which seed could not pass. The lint was removed from the saw teeth by means of a doffer brush. This machine gave about 300 lb. of cotton per day, as compared with about five to eight lb. with the roller gins of that time. Saw gins have since been modified and improved in various directions and are extensively employed for ginning cotton in the United States and other countries.

This gin, however, is not suitable for ginning very long staple cottons and for this purpose, Macarthy invented, some 50 years later (Bowman, 1908), the gin that goes by his name. It consists of a leather roller against which the 'doctor' knife is pressed tightly as in the earlier gins. Spiral grooves of the roller carry away the fibres, and hold them firmly between the roller and the 'doctor' knife, while the seed which cannot pass is beaten away by a blunt steel blade, which moves up and down by means of a crank shaft. The lint that is thus released from the seed is removed for the roller by a stripping device, while the detached seeds drop down through the grid. In the beginning, different modes of fitting the fixed knife and several types of beating motions of the moving knife were experimented upon (Watson, 1879), and finally the present arrangement of the fixed knife and the beater were adopted. Several types of Macarthy gins are in use at the present day, some of which will be described later.

Ginning was a slow process in the earlier days and the seed cotton, lint and seed were handled by manual labour. In the modern saw gin factories, very high production is attained by handling the material by mechanical means. The seed cotton is sucked in by means of air draught at one end and the lint is conveyed to the pressing box at the other, while the seeds are delivered into a seed-store by means of conveyors. The rate of production has increased several hundred times, enabling a very large volume of seed cotton to be disposed off in a short period. It is such ginning factories that have enabled the United States to cope with the extensive production of cotton in that country.

PRESENT POSITION IN INDIA

GINNING

The position of the ginning industry in India was recently investigated through a survey undertaken by the Technological Laboratory (Nanjundayya and Iyengar, 1957). Although the findings of the survey cannot be taken to be very exact, they may be considered as giving a rough idea of ginning conditions in India at present.

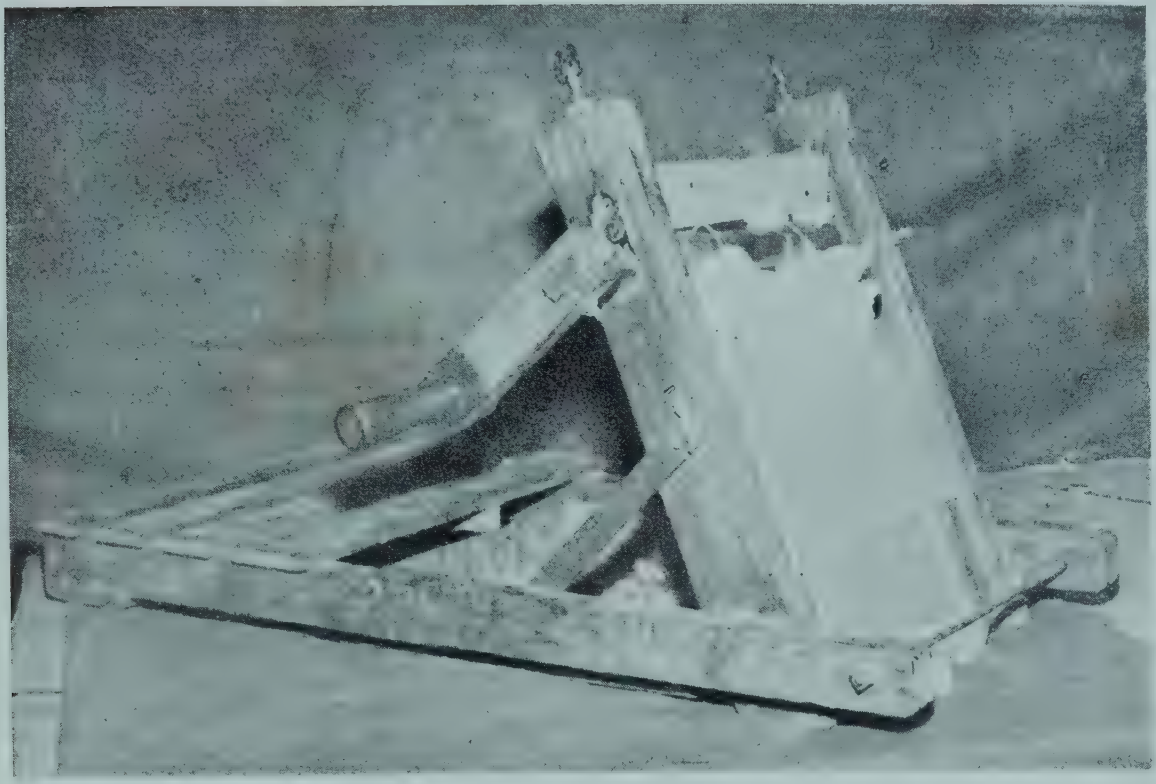
Before considering ginning proper, it would be more logical to deal with some of the allied operations preceding actual ginning, viz., handling of seed cotton, its storage and cleaning, etc. They are dealt with below.

Handling of Seed Cotton. The seed cotton which arrives at the ginning factory in carts or trucks is handled invariably by manual labour only. It is first stacked, then transported from the stack to the gin-shed by manual labour, there being no mechanical equipment for this purpose. In some of the recently erected factories, in which saw gins are installed, the handling is almost completely done by mechanical or pneumatic equipment of the type shown in Plate V b. The seed cotton is sucked in through telescopic pipes from the heap and supplied, through the pre-cleaning machines, to the gins. The lint is conveyed to the press, from which it is delivered in the forms of bales.

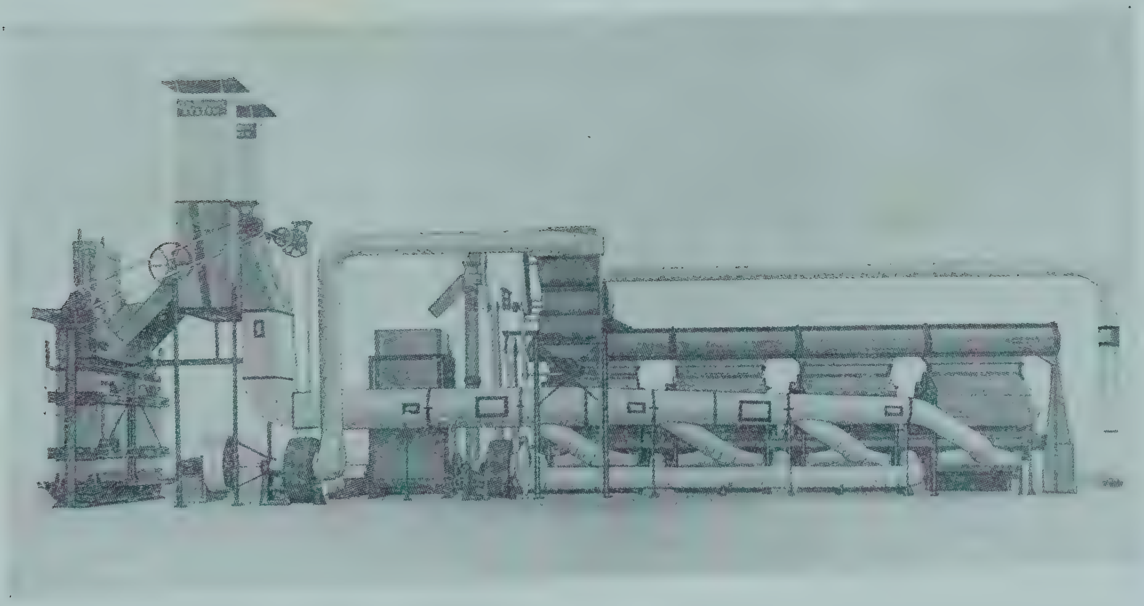
Storage of Seed Cotton. The storage conditions of seed cotton are, for the most part, unsatisfactory. Godowns are very rarely provided and the seed cotton is generally stacked in the open yard of the ginning factory, sometimes on bare ground exposed to the sun and wind. During inclement weather, protection is provided by covering the heap with tarpaulins or other material. Fortunately, however, during these months the rainfall is meagre. Yet, the quality of the lint would be affected by exposure to sun, wind and dew. A few safeguards are provided against fire hazards.

Cleaning and Drying of Seed Cotton. The harvested seed cotton is often quite trashy necessitating pre-cleaning before ginning. This, however, is not generally done in India. In a few instances, it is done by manual labour employed for this purpose and in a few others, locally made cleaners are used. Standard cleaning equipment of the type of Platts Opener (Plate VI) is employed only in a few factories.

In this connection, it may be mentioned that several types of pre-cleaning machinery have been evolved for this purpose. They may be broadly grouped into two classes: (*i*) cleaners; and (*ii*) extractors. A combined cleaner and extractors units is shown in Plate VII. The cleaner opens out locks, lumps and unopened bolls, disintegrates the clods formed by burrs and other trash by making them loose and free for easy ginning. Extractors are machines designed to separate coarse foreign matter, such as hulls, burrs, stems, stones and also immature locks from carelessly picked seed cotton. Extractors later would



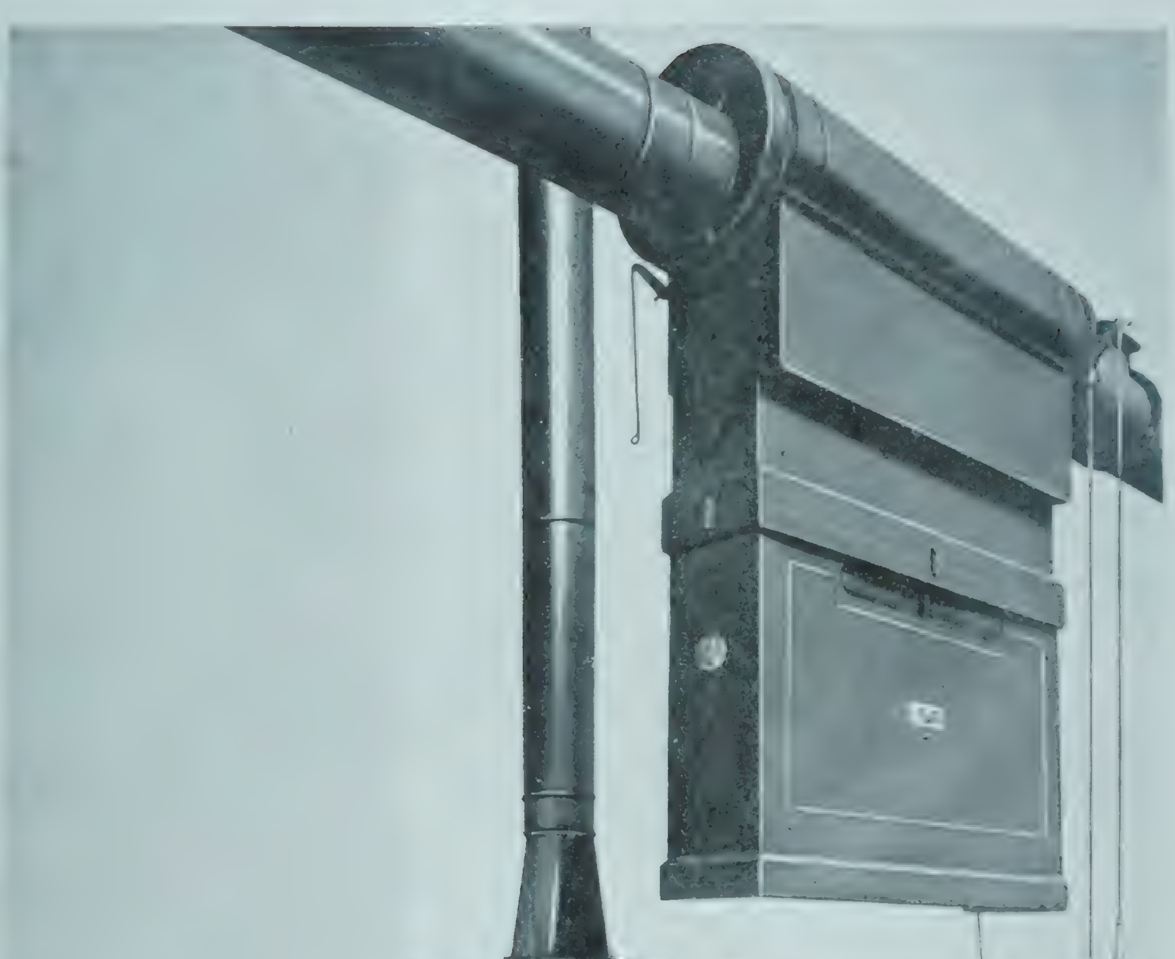
a. Bardoli Gin



b. Mechanical Equipment for Handling *Kapas* and Lint with a Cotton Press
(The arrangement for Feeding a unit of four Saw Gin Stands)

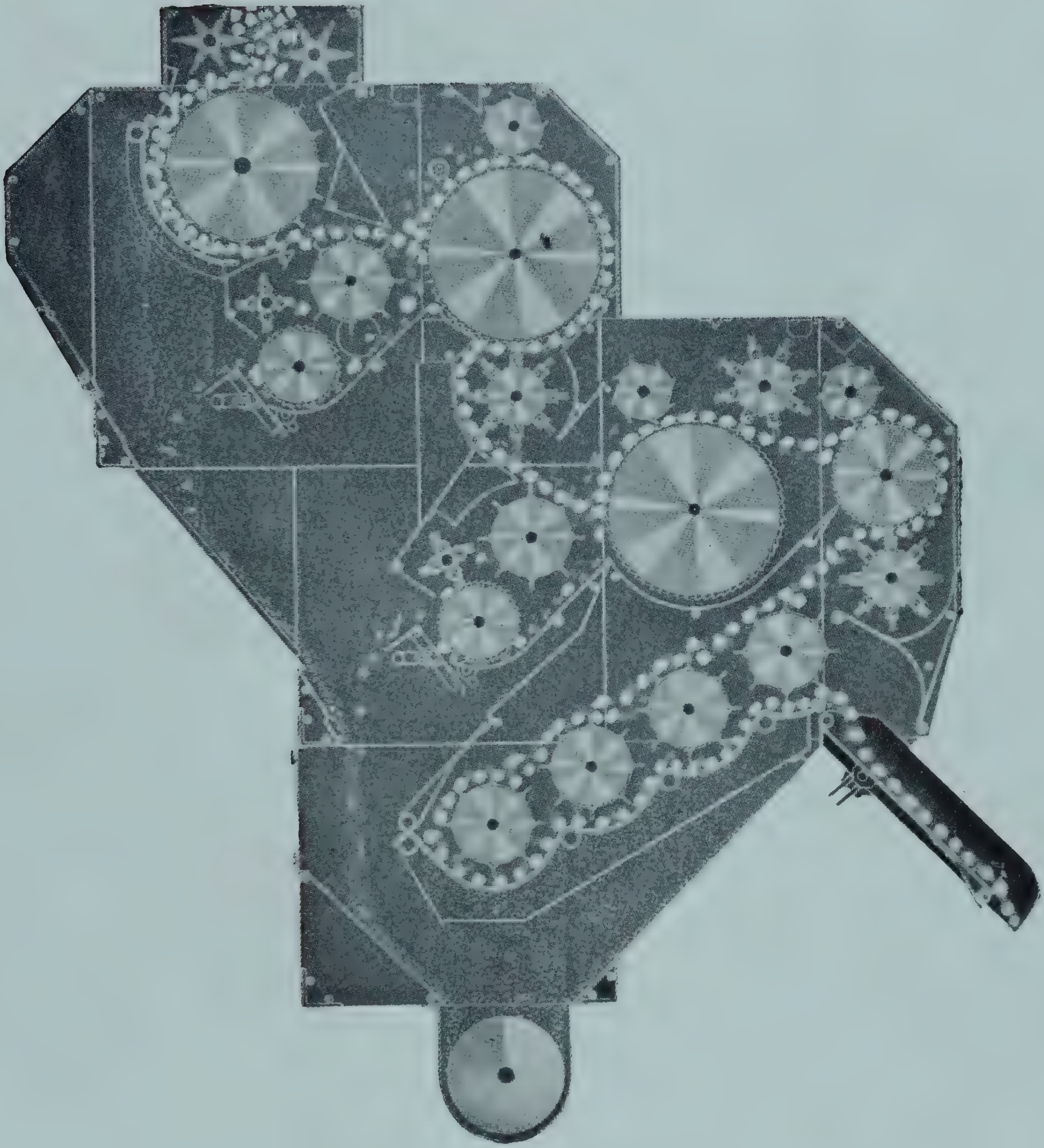
(*By Courtesy of the Cen-Tennial Cotton Gin Co., Dallas, Texas, U.S.A.*)

PLATE VI



Platts Double Cylinder Seed Cotton Opener with Automatic Feeding Arrangement

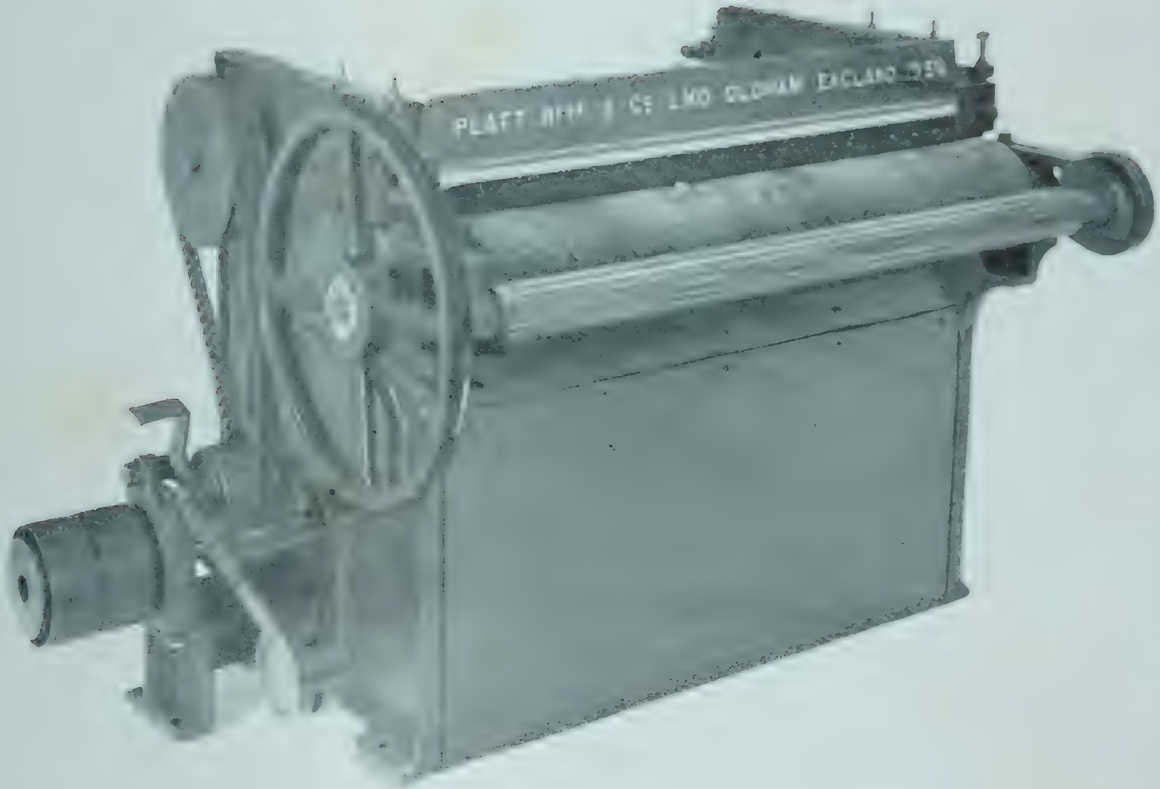
(By Courtesy of Platts Bros. Ltd., Oldham, England.)



Combined Cleaner and Extractor Unit

(By Courtesy of the Continental Gin Company Dallas, Texas, U. S. A.)

PLATE VIII


PLATT BROS & Co LTD OLDHAM ENGLAND

Ball and Roller Bearing Single Action, Single Roller Gin

(By Courtesy of Platts Bros. Ltd., Oldham, England)

be absolutely necessary in a country like the United States where, on account of the high cost of labour, the picking is done in a very trashy condition either when hand-picked or hand-snapped or machine-picked. It would also be required in our country where such type of trash is present in the seed cotton.

An example of the extractor is the Finishing Extractor Cleaner (F.E.C.) machine installed at the Technological Laboratory (Sen and Venkataraman, 1951). The Hardwicke Ettar's Inclined Cleaner (H.E.) machine and the Platts Opener are examples of the cleaner. It would be worthwhile using the appropriate cleaning equipment in our country wherever necessary.

Seed cotton is sometimes dried in the sun before ginning. Drying is rarely done in India by means of hot air driers, as in other countries (Bennet, 1931), nor is it necessary in India, where the atmospheric conditions are generally hot and dry. The result is that the moisture content of the seed cotton is usually within the critical limit.

Types of Ginning Machinery. All the gins used in India for commercial ginning are roller gins designed on the Macarthy principle, except for a few saw gins which have recently been installed. Besides, there are also a number of hand gins, mostly of local make, which are employed in villages for domestic use of cotton. However, as these are concerned with only a small production and are not of importance from the commercial point of view, they need not be considered here. A brief description of the different types of gins in use is given below :

Single Roller Gin : This gin (Morris, John and Wilkinson, 1897) is of the Macarthy type, with a leather roller, spirally grooved, usually 40 inches long. Two kinds of them are generally employed in India, one with a single moving knife (Plate VIII and Fig. 21), the other with two moving knives (Plate IX). In the latter, both the knives are mounted on the same crank shaft so that the machine is balanced, and the number of strokes are doubled for the same crank shaft speed, which helps to remove the fibres at a faster rate. Thus, the output of lint is very much improved, especially in the case of short stapled *desi* cottons. However, this type of gin is not quite suitable for ginning long staple cottons and the fuzzy-seeded American varieties.

Double Roller Gin : This gin is, in fact, a combination of two single roller gins in one unit, in the inverted position (Plate X) (Morris, John and Wilkinson, 1897), with the roller of the same length as in the single roller gin. As the feeding for both the rollers is effected at the same time by the same person, there is considerable saving in labour charges by using this gin.

Saw Gin : The saw gin, in its modern form, consists of 80 to 90 saw discs in each stand (Plate XI); three or four such stands make an economic unit. The fibres pulled away from the seeds by the saw teeth are stripped from them by means of an air blast and delivered out after condensing them into a continuous bat of lint. Several cleaning and moting arrangements are added to the gins which help to produce clean lint. The average output of lint is about eight times that of a roller gin of corresponding roller length.

The ginning machines most frequently used for commercial ginning of cotton in India are as follows:

A majority of the factories—in fact, about three-quarters of the total number—are equipped with single roller gins, while the remaining quarter is equipped with double roller gins; about a dozen factories have saw gins. The double roller gins are predominently found in the southern part of the Peninsula, in the States of Madras, Mysore and Andhra Pradesh.

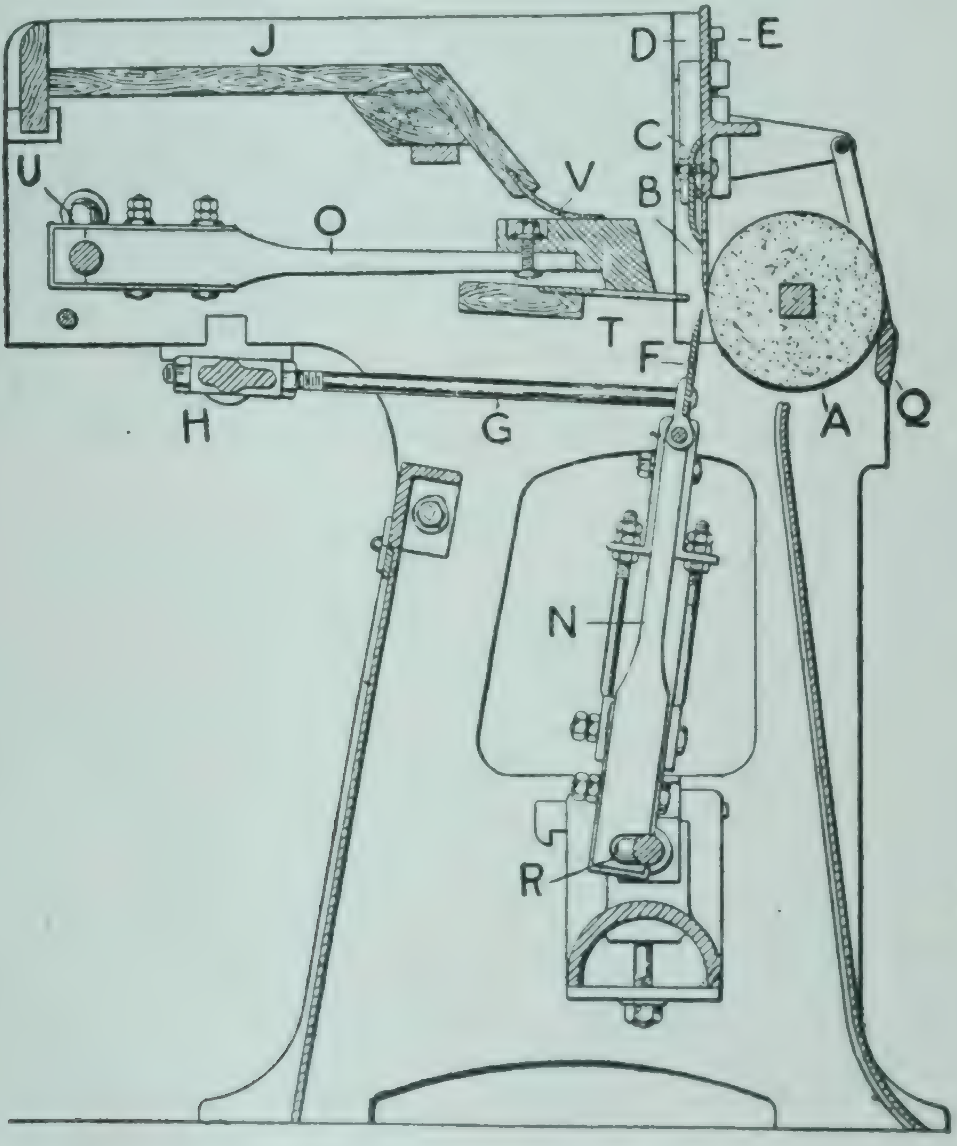


Fig. 21. Single Action, Single Roller Macarthy Gin (Sectional View)

None of the gins mentioned above are manufactured in India. They have to be imported from abroad. Most of the spare parts are also imported, while repairs to the gins are done locally. It is worthwhile considering whether it would not be feasible to undertake manufacture of gins and the spare parts in our own country.

Condition of Ginning Machinery. The condition of ginning machinery functioning in the factories at present leaves much to be desired. The machinery is mostly old, some of the gins being a century old. About one-third of the total number of factories contain gins which are more than 50 years old, while about half the number have gins which are between 30 and 50 years old. Of the remaining many have gins which are more than 20 years old. Thus it will be noted that most of the gins installed are quite old. Further, they are not maintained by trained fitters and hence the condition of the gins, in general, cannot be considered satisfactory.

Size of Factories. The number of gins in a factory ranges from three or four to over a hundred. About a quarter of the total number of factories in India possess less than 10 gins, and about half the number of factories 10 to 40 gins; only some four per cent. of them have more than 70 gins. Thus predominently, the factories are small-sized, which is probably necessitated by various economic factors, like small production of cotton, lack of, or high cost of transport, insufficient finance, etc.

This state of affairs is not conducive to maintaining the efficiency of ginning factories at the desired level. For instance, such small factories cannot afford to employ adequate staff of trained gin fitters, mechanics, etc., to look after the maintenance of the gins and the motive power in optimum condition. Further, it is difficult in these small factories to enforce the regualtions under the Ginning and Pressing Factories Act, which has been enacted for preventing malpractices, adulteration of cotton and seed mixing. By bringing such small-sized units, in certain regions, under a co-operative organisation, which may render the required technical guidance and service, it may be possible to overcome some of the defects mentioned above.

Number of Factories. The number of ginning and pressing factories in India is given in Table 16 (the figures are from the Bombay Cotton Annual 1955-56). The data correspond to the priod ending with December 31, 1954, as more up-to-date data are not yet available on account of the re-organisation of the States.

It will be noted that in 1954 there were about 2,500 ginning and pressing factories in India employing about 1,37,000 persons. It may be pointed out, however, that these figures require verification and, possibly, some revision, because a recent survey has shown that some of the factories are not in working condition. However, taking the data as they are, it may be stated that though the total number may be large enough, the distribution of the factories is not quite satisfactory. While in some regions there are too many factories competing with one another, resulting in under-working or closure of some of them, in other regions the *kapas* has to be carted over large distances for being ginned. On the whole, the number of factories in India appears to be much more than necessary. Some of them may have to be closed down, as they have very old and dilapidated machinery and some others may have to be shifted to regions where they are in greater need.

TABLE 16. GINNING AND PRESSING FACTORIES IN INDIA (1954)

State	Number of ginning and pressing factories	Average number of persons employed daily
Ajmer	13	239
Andhra	99	3,273
Assam	6	418
Bhopal	10	386
Bihar	1	20
Bombay	763	43,240
Hyderabad	215	12,951
Kutch	8	497
Madhya Bharat	326	23,447
Madhya Pradesh	344	25,946
Madras	214	10,364
Mysore	37	1,639
Pepsu	75	815
Punjab	146	4,689
Rajasthan	42	2,086
Saurashtra	116	6,571
Uttar Pradesh	15	604
West Bengal	10	282
Total	2,440	1,37,467

Motive Power. In many of the areas growing cotton, electricity was not available and hence either steam or diesel engine was employed as motive power. For large-sized factories, the motive power is generally the steam engine, while for the smaller units it is either steam or diesel engine. Only 10 per cent. of the factories use electricity. However, there is a trend to convert to electricity, wherever it becomes available. For orderly distribution of coal to the ginning factories after the Second World War, supplies are being supervised by the Indian Central Cotton Committee on behalf of the Government of India.

Ginning Charges. The charges for ginning vary widely, both within a State and between States (Nanjundayya and Iyengar, 1957). The average charges for each State are given in Table 17.

It will be noted that the highest average charge is Rs. 30 in West Bengal, for ginning the short stapled Comilla cotton. It is Rs. 10.31 in Madras for ginning Karunganni and Cambodia cottons. Apart from the values for Andhra Pradesh of Rs. 18.56 and Rajasthan of Rs. 17.37, the average for other States lies between Rs. 11 and Rs. 15. In Madhya Pradesh, the variation within the State is the least as most of the factories charge Rs. 11. The remaining charge a little more or less and the excess goes to the 'pool', for payment to the factories that are rendered idle. In Bombay State, it is understood that the Government fixes the ginning charges.

TABLE 17. AVERAGE GINNING AND PRESSING CHARGES OF A BALE OF COTTON

State	Average charges for ginning a bale of cotton (Rs.)	Average charges for pressing a bale of cotton (Rs.)
Andhra	18·56	12·00
Assam	19·00	11·31
Bombay North	12·37	12·00
Bombay South	15·06	11·56
Hyderabad	13·50	11·25
Madhya Bharat	15·00	9·44
Madhya Pradesh	11·12	10·00
Madras	10·31	9·44
Pepsu	15·00	7·00
Punjab	14·25	8·00
Rajasthan	17·37	10·44
Saurashtra	12·00	12·25
Uttar Pradesh	15·00	10·00
West Bengal	30·00	12·00

Operation of Factories. The ginning factory is essentially a seasonal factory. It works from three to eight months depending upon the quantity of the seed cotton received by it. For the remaining period it is idle and is, generally, shut down. This state of affairs applies to about three-fourths of the total number of factories in India. Some of the remaining factories, however, have alternative employment during the off-season. Most of them do oil extraction and groundnut decortication; some of them use it as a flour mill. The small units utilise the power for such purposes as rice-hulling, saw mill, ice plant, etc.

Being seasonal factories the application of labour laws to the cotton ginning factories causes hardship to the factory-owners. This might have to be looked into.

PRESSING

Types of Machines. The necessity of cotton pressing, as has already been stated, is to compress the bulky material like cotton lint into such a form as can be handled and transported conveniently from one place to another. Generally speaking, two levels of compression are usually employed. One is the *katcha* where the package is done crudely in a *borah* at low compression for easy transport of cotton over short distances. The other is *pucca*, where a high density bale of approximately standard dimensions is produced, for transport over long distances. There are three distinct types of compression equipment in use for this purpose at present, viz., steam cylinder, hydraulic and geared mechanical (Wright, 1940). However, several makes of each of the first two types, with changes in constructional details, exist in India. The bales pressed are usually called square bales, in contrast to cylinderical bales (Sen and Venkataraman, 1951). Usually, the pressing is done in India in two stages. A definite weight of cotton is fed into the first container, where it is pressed into a bale of low pressure. This is then transported, by means of a bale holder, to the second press, where it is fully compressed and covered with hessian bagging and tied with flat steel hoops. The gross weight of the Indian cotton bale is 400 lb., of which about eight lb. account for the bagging and hoops. The normal weight of the American and fully pressed international bale is 500 lb.

The dimensions of the Indian bale are not quite standardised. Its length varies from 48 to 50 inches, width from 16 to 20 inches and thickness from 15 to 18 inches; the density of the bale varies from 35 to 40 lb. per cubic foot.

Number of Pressing Factories. In India, the pressing factories are not invariably attached to the ginning factories, nor do all ginning factories have their own presses. Thus there is a number of factories for pressing only. The number of presses in India is given in Table 18.

TABLE 18. PRESSING FACTORIES IN INDIA BY STATES (Year ending December 31, 1954)*

State	Number of presses
Ajmer	12
Andhra	25
Assam	6
Bhopal	3
Bombay	283
Hyderabad	78
Kutch	4
Madhya Bharat	62
Madhya Pradesh	121
Madras	22
Mysore	12
Pepsu	44
Punjab	80
Rajasthan	48
Saurashtra	37
Uttar Pradesh	21
West Bengal	6
Total	864

* More up-to-date data are not available on account of the re-organisation of the States.

It will be noted that there are about 864 pressing factories in India. Each of them is given a certain mark and a number for identification.

Pressing Charges. Like the charges for ginning, those for pressing also vary from State to State as well as within a State (Nanjundayya and Iyengar, 1957), as can be seen from Table 18. It will be noted that the range of variation of pressing charges is not as large as in the case of ginning charges. The average ranges from Rs. 7 for Pepsu to Rs. 12.25 for Saurashtra. Except for the Punjab, Madras, Madhya Bharat, and Uttar Pradesh which charge Rs. 10 or less, all the other States charge, on an average, between Rs. 11 to Rs. 12 for pressing a bale of lint.

MALPRACTICES AND REMEDIAL MEASURES

Many types of malpractices are prevalent in the cotton ginning and pressing industry (Bhaiya, 1957). Watering of cotton is most common for increasing the weight of the baled cotton. Adultration of superior cotton with inferior one, either in the gin or in the press is also prevalent. Heavy trash and other foreign matters are either deliberately or carelessley mixed with the lint. Sometimes, quantities of seed cotton are also found along with the lint. Bad ginning, done deliberately or due to improper machinery, is another common feature.

For remedying these defects, the Government of India and Governments of the cotton growing States have passed legislations under the Cotton Transport Act and the Cotton Ginning and Pressing Factories Act. Certain areas are declared as 'protected areas', where only certain superior varieties of cotton are allowed to be cultivated. Inferior varieties grown in the neighbouring areas are not permitted to be transported to the protected area, in order to prevent admixture with the superior one. Every bale of cotton is required, according to law, to have a press mark as well as a serial number stamped on it, from which it would be possible to identify the press in which the bale was pressed and the party for whom the pressing was done. Thus, in case of detection of any malpractice in a particular bale, its origin can be easily traced to the press-owner and the party concerned, so that necessary action can be taken against the offender. Further, gin sheds are to be provided with a separate entrance for seed cotton to be brought in and a separate exit for lint to be taken out, after ginning; this is in order to prevent the former getting mixed up with the latter.

Unfortunately, however, there is no administrative set-up whereby the owner of a ginning factory is given guidance for improving the quality of ginned cotton nor is there any machinery for its enforcement. The Indian Central Cotton Committee has recently proposed a liaison officer under the Director of Agriculture of each cotton growing State for filling up this lacuna. It is hoped that this arrangement will prove helpful.

RESEARCH

INVESTIGATIONS

As stated earlier, in order to improve the condition of ginning in Indian factories, several investigations were undertaken at the Technological Laboratory. Pre-cleaning and ginning tests were carried out almost on all the important varieties of Indian cottons to determine the optimum cleaning treatments for the seed cotton, and settings and speeds in both saw gins and roller gins. The results of these tests have been published as Technological Leaflets which are distributed among the ginning factories and others interested, for their information. Further, these results are compiled as a consolidated report on the pre-cleaning and ginning test on Indian cottons (Sen and Venkataraman, 1951). The results obtained for the trash content and the ginning percentage for different varieties are given in Tables 19 and 20.

TABLE 19. TRASH PERCENTAGE OF DIFFERENT VARIETIES OF INDIAN SEED COTTON

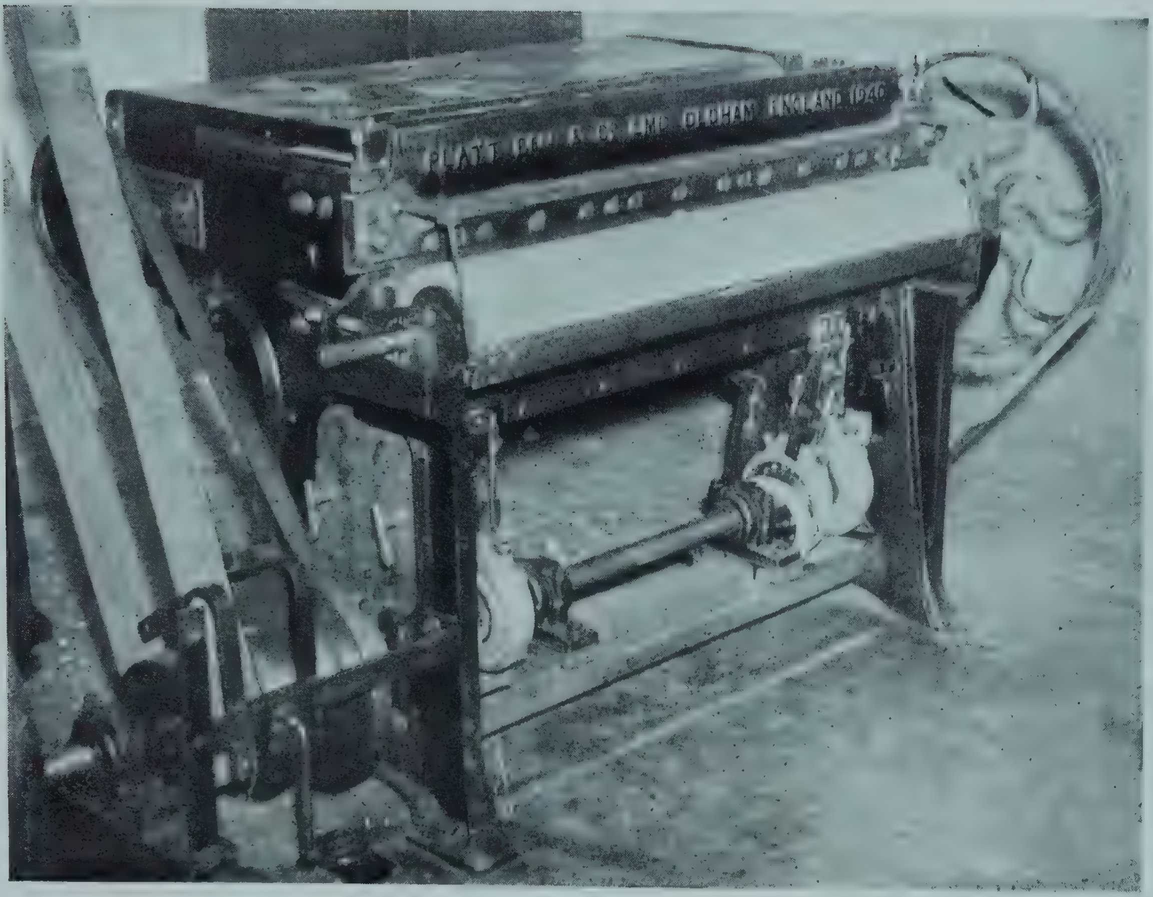
Variety	Type of opener			Mean
	Platts	F. E. C.*	H. E.**	
Jayawant	1·02	1·57	1·20	1·26
Surat 1027 A L. F.	0·79	0·85	0·65	0·76
Jarila	1·80	1·85	1·68	1·78
Wagad	3·70	4·55	3·72	3·99
Verum	1·70	1·80	2·60	2·03
Umri-Bani	1·90	1·92	2·20	2·00
Gaorani 6	4·40	3·95	3·58	3·98
Suyog	0·95	0·55	0·55	0·68
Co.2	0·89	0·62	0·34	0·62
Laxmi	2·00	1·56	1·47	1·68
Karunganni	1·84	2·27	1·89	2·00
Westerns 1	2·70	2·77	2·45	2·64
M. U. 1	0·87	1·27	1·10	1·08
Kalyan	2·12	2·33	1·68	2·04
Jayadhar	0·98	1·34	1·10	1·14
320F	1·10	1·09	0·89	1·01

* Finishing Extractor Cleaner.

** Hardwicke Ettar's Inclined Cleaner.

TABLE 20. GINNING PERCENTAGE OF DIFFERENT VARIETIES OF INDIAN COTTONS

Variety	Single roller gin	Double roller gin	Saw gin
Jayawant	27·4	27·3	26·6
Surat 1027 A L. F.	34·5	34·5	34·0
Jarila	32·9	33·0	31·5
Wagad	35·8	36·8	34·1
Verum	29·9	29·9	28·5
Umri-Bani	26·9	27·0	25·6
Gaorani 6	30·4	30·8	29·6
Suyog	35·0	35·0	34·6
Co.2	32·7	32·9	32·1
Laxmi	35·2	36·2	35·1
Karunganni	27·6	28·2	26·7
Westerns 1	27·2	27·6	27·0
M. U. 1	30·5	30·2	29·8
Kalyan	39·8	40·1	38·2
Jayadhar	30·4	30·5	29·8
320F	33·2	33·0	32·0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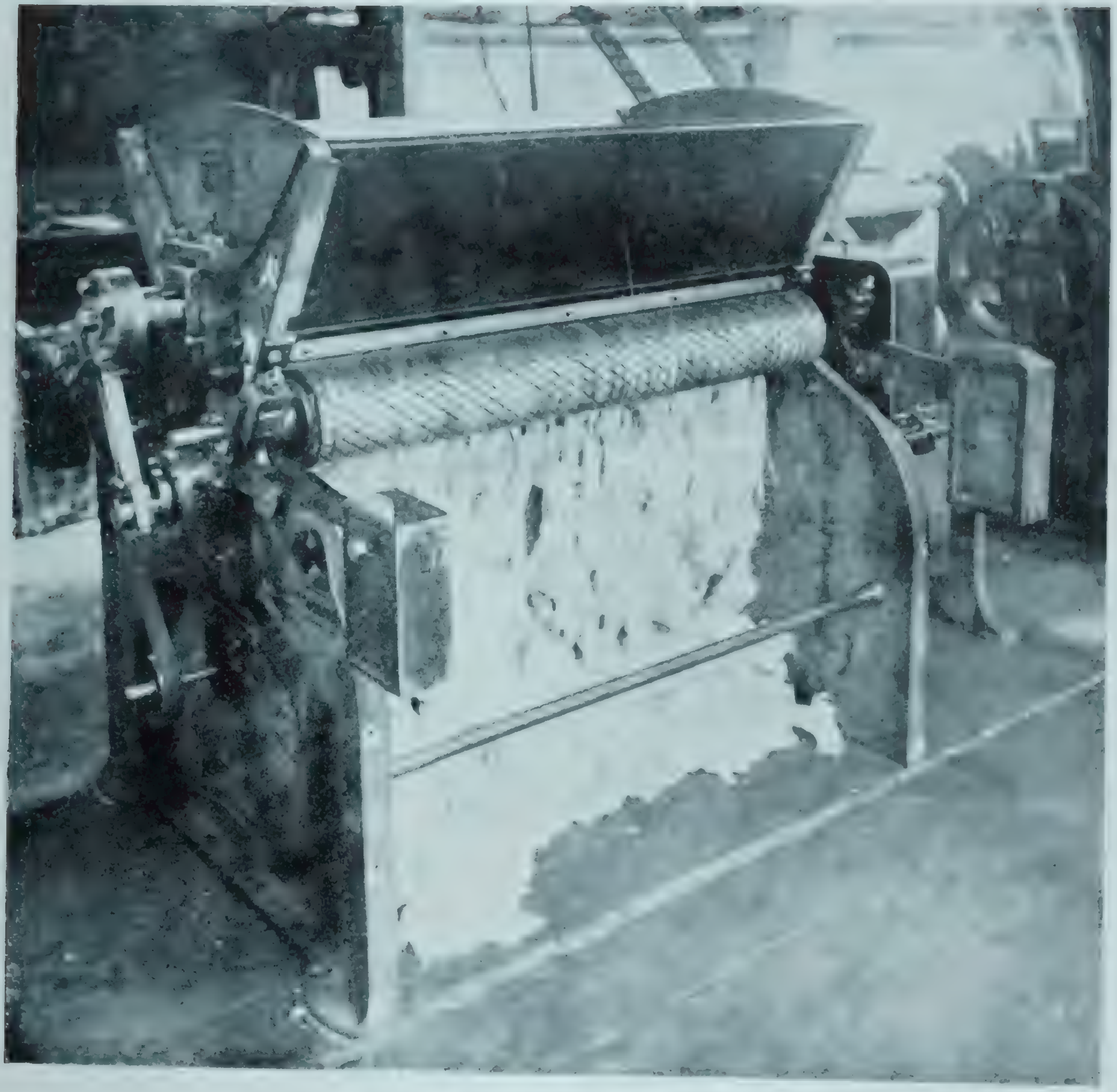
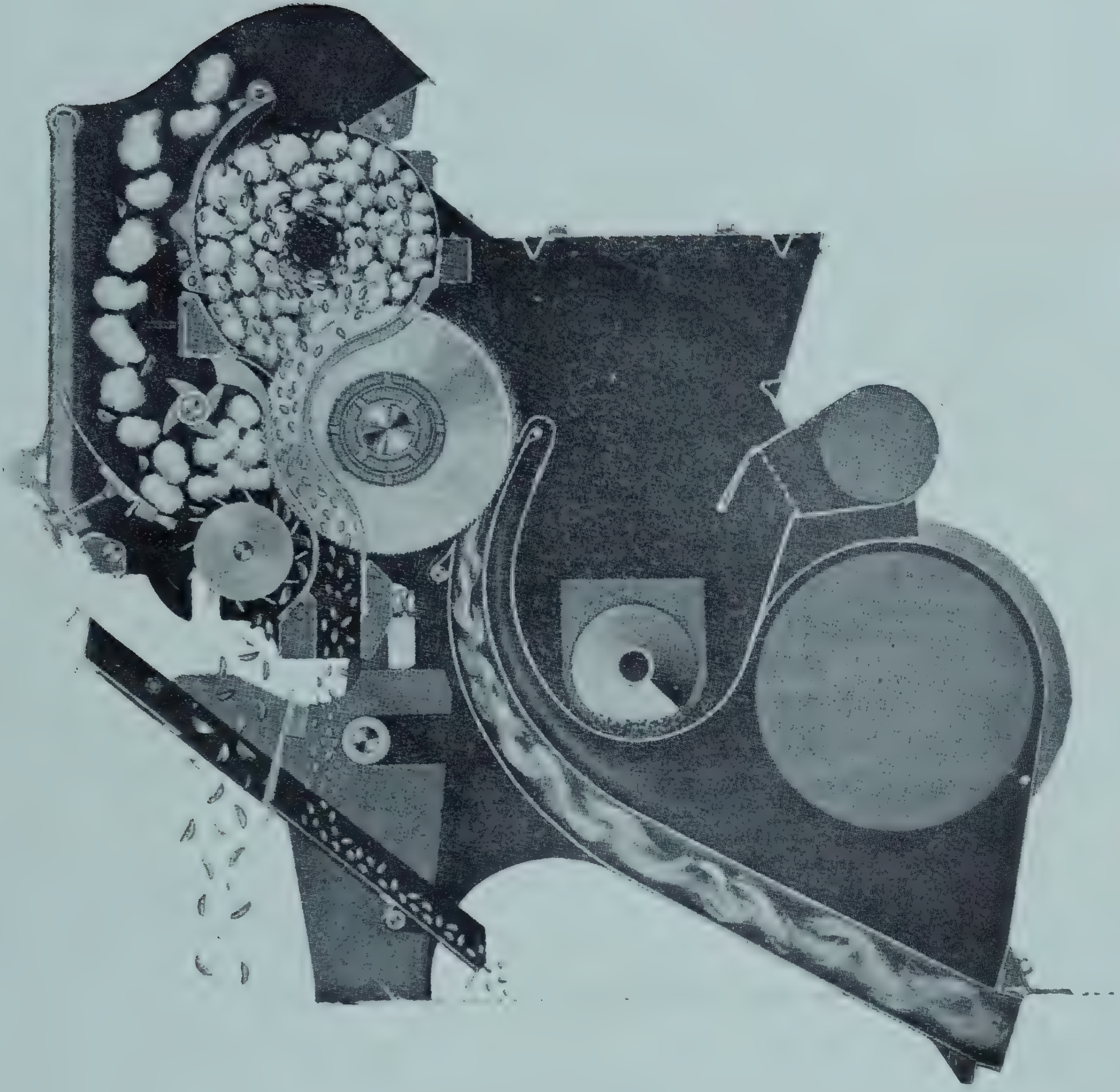
Double Action, Single Roller, Macarthy Gin, Fitted with Ball-Bearings
(The covers of the bearings have been opened out to expose the ball-bearings)

PLATE X



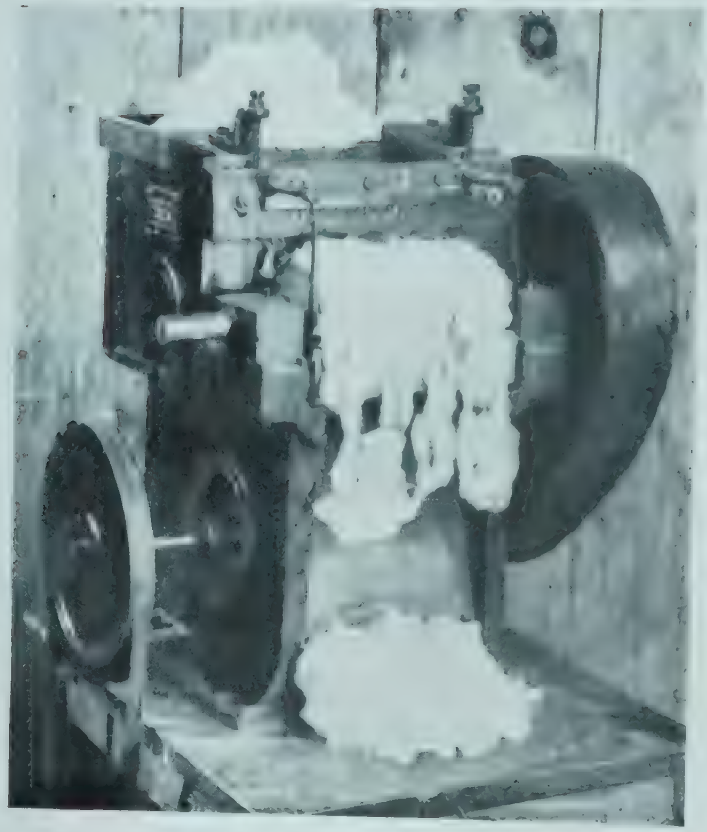
Double Roller Gin

(By Courtesy of Platts Bros. Ltd., Oldham, England)

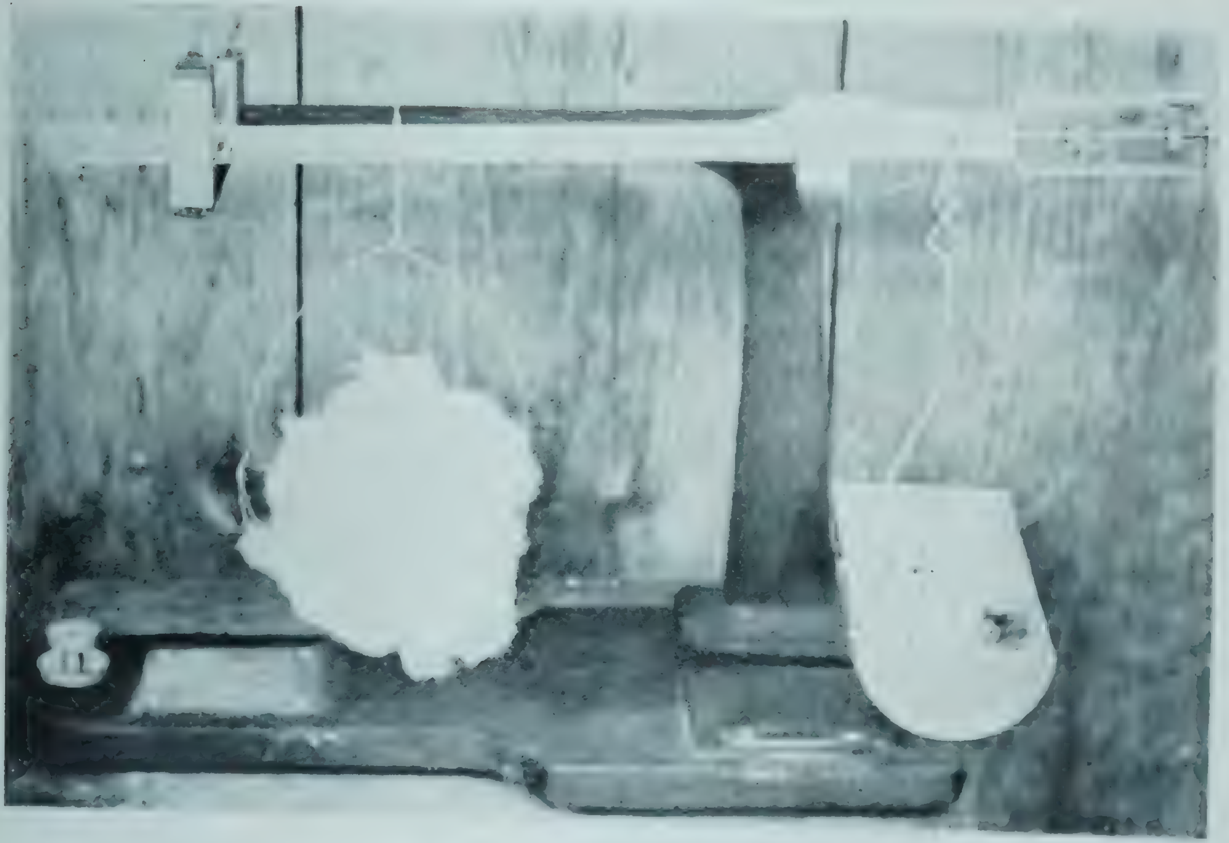


Air Blast Saw Gin

(By Courtesy of the Murray Company Texas, U.S.A.)



a. Laboratory Gin



b. Ginning Percentage Balance

It will be noted that some varieties are clean, containing less than one per cent. trash, a majority of the others contain one to two per cent. trash, while only a few contain more than three per cent. Cottons with more than three per cent. trash should definitely be pre-cleaned before ginning. It may also be of advantage to clean those having more than two per cent. trash. If the seed cotton contains an appreciable quantity of immature locks, it will be necessary to remove them by using extractors. If, on the other hand, it contains more of leafy matter, an opener of the Platts type may be desirable. Thus, the type of opener that would serve best for a particular variety would depend upon the kind of trash it contains. In the United States the most common practice is to have an inclined cleaner followed by an extractor. More cleaning points would be introduced as and when necessary. Pre-cleaned cottons, in general, and those open in Platts opener, in particular, gave generally a higher output of lint per hour. This feature was specially noteworthy in the case of short staple cottons.

As regards the gin speeds, higher speeds in the roller gins increased the output of lint per hour up to a certain limit. But higher speeds cannot be recommended for ginning factories, where continuous working may over-heat the rollers.

The foregoing findings were from tests carried out at the Technological Laboratory only, where the conditions of relative humidity and temperature may not be the same as those at upcountry ginning factories. It was, therefore, considered necessary to carry out comparative tests both at the Laboratory and at several ginning factories, using the same sample of cotton at both the places, in order to see how far the Laboratory findings are applicable to the factories. Such tests were carried out in three ginning factories (Iyengar and Sen, 1949) and results obtained confirmed their applicability.

Investigations were also undertaken to determine the difference, if any, between the saw ginned and roller ginned lint (Nanjundayya and Iyengar, 1944). It was found that although the saw gin gave a lower ginning percentage, the lint obtained from it was more regular. However, it was slightly weaker consequent upon some injuries to the fibres. On the other hand, it gave lower blow-room loss and card loss, especially lower fly waste. Further, in some cases the saw ginned lint gave slightly stronger, although somewhat more neppy, yarns than the roller ginned, but not so in others. Some of the differences noted above could be linked to the difference in the ginning action of the two types of gins. The saw gin is not capable of catching and removing the shorter, and incidentally coarser, fibres from the seed to the same extent as a roller gin can. The absence of such fibres in the saw ginned lint is responsible for the greater regularity, lower fly waste and slightly improved yarn strength noted in some cases. On the other hand, the slight reduction in the strength of fibres due to the injuries by the saw tends to lower the spinning performance to some extent. However, the combined effect of all these factors is to make the spinning quality of both the saw ginned and the roller ginned lint nearly the same. The saw gin would score a distinct advantage over the roller gin by giving a very high output and producing a much cleaner lint.

The advisibility of cleaning the cotton before baling was investigated by cleaning the lint with Crighton Opener before it was pressed into a bale (Iyengar, Oka and Sen, 1949). The lint samples were also valued by graders in order to ascertain the economics of this process. The test results, as well as the valuation data, showed that the premium offered for the cleaned lint was not sufficient to offset the loss in weight and the expense involved in the cleaning. This treatment is not feasible for sale of cotton in the open market. However, it would be beneficial for a mill having its own pressing factory to adopt this process as it would save the freight and other charges, besides supplying them with cleaner lint.

In addition to the investigations concerning the economic factors, another, dealing with the fundamental aspect of the strength with which the fibre was attached to the cotton seed in relation to the work done and the power consumed in ginning the cotton was also undertaken (Iyengar, 1954). It was found that the strength of attachment varied considerably from variety to variety and from species to species and that there was a good co-relation between this strength and power consumption in ginning.

IMPROVEMENT OF MACHINERY

The single roller gin, which is normally used in the ginning factory, contains a number of bush-bearings. These bearings offer appreciable friction, thereby consuming a large amount of power, besides causing considerable operational and lubrication difficulties during ginning. In order to minimise them, the bush-bearings were replaced by ball-bearings and test results show an improvement of about 30 per cent. in power consumption besides advantages in other directions (Nanjundayya, Iyengar and Shete, 1955). These were brought to the notice of the ginning factories, some of whom have installed ball-bearings in their gins and derived benefit therefrom.

Many of the single roller gins in India are of the double action type, i.e., having two moving knives instead of one as already described. While these are pre-eminently suited for ginning short and medium staple *desi* cottons, they offer considerable difficulty in ginning long staple and large-seeded Amerigan varieties to overcome this handicap, the double action gin was converted into a single action gin by removing one of the knives, introducing a fly wheel to prevent vibrations and making other necessary arrangements. By this conversion (Nanjundayya, Iyengar and Shete, 1955), not only was the output increased for these varieties, but most of the operational difficulties were overcome and the quality of lint was improved. Some of the ginning factories have introduced this transformation and benefited thereby.

Besides these, a standard method for determining the ginning percentage of small samples of cotton was established in the Laboratory (Iyengar and Sen, 1949). For ginning these small samples, a small gin (Plate XIIa) of the Macarthy type, having a seven-inch roller length, with chain drive and with crank shaft mounted on ball-bearings, was designed (Oka, Iyengar and Nanjundayya, 1956). Further, in order to determine the ginning percentage of a large number of small samples rapidly, a ginning percentage balance (Plate XIIb) was devised and patented by the Laboratory (Iyengar, 1955). This balance and the gin have been provided to almost all the cotton breeding stations in India and to some of the seed cotton markets, where several hundreds of samples have to be examined within a short time. The combination of these two instruments has met this demand and has saved immense labour and time involved in these determinations. One of these balances has been supplied to the United States also. Enquiries have been received for the supply of five balances to United Arab Republic.

The problem of improving ginning of Indian cottons is being vigorously tackled in all its aspects for the last 16 years.

TRAINING IN GINNING

It was noted from the ginning survey, mentioned earlier that most of the ginning factories were not manned by well-trained gin fitters. In fact, many of the fitters were illiterate and their technical knowledge could not be properly assessed. To remedy the drawback, a course of training has been instituted at the Technological Laboratory. It is given free of charge, and each course lasts for a fortnight. The training comprises of instructions in: (*i*) proper operation of the ginning machines with emphasis on preserving the lint quality; (*ii*) economic use and maintenance of ginning machinery; (*iii*) practical ginning operation with typical Indian cottons in different types of gins; and (*iv*) dissemination of technical information based on the researches carried out at the Technological Laboratory on pre-cleaning and ginning of Indian cottons and other investigations, and also the available literature on the subject from other countries.

MEASURES FOR FUTURE IMPROVEMENT OF GINNING

In the light of the earlier discussion and the findings of the economic and technical survey undertaken by the Technological Laboratory, the following measures may be suggested for improving the working of ginning factories in India.

1. Well ventilated sheds should be provided in the factories for storing seed cotton, wherever necessary, to prevent damage due to rain, dew, sandstorms, etc.
2. Trashy seed cotton should be cleaned before ginning and suitable pre-cleaning machinery installed for this purpose. It is necessary to keep

a check on the quality of the cleaned cotton to ensure that the cleaning is effectively carried out. Appropriate premium should also be paid for cotton which is ginned after pre-cleaning to encourage the marketing of clean cotton.

3. A large number of gins are old and obsolete and these should be replaced.
4. In certain areas, there are far too many ginning factories for the amount of cotton produced. This has resulted in unhealthy competition, which in turn makes ginning uneconomical. Suitable steps have to be taken to scrap old gins and to distribute the ginning factories appropriately, so as to serve each particular cotton ginning zone in an economic manner. Licences for new factories should be granted with an eye on the suitability of the place and the type of machinery to be installed; for example, a saw gin may be installed in areas where American varieties of cotton are grown extensively.
5. All the ginning machinery and most of the spare parts are being imported. Considerable difficulty is being experienced in getting new machines and the spares. It is, therefore, necessary to give serious consideration to the feasibility of undertaking the manufacture of gins and spare parts of appropriate quality in our own country.

   In this connection, it is also worthwhile considering whether some of the older gins can be reconditioned by installing ball-bearings and making other necessary changes. This may save considerable foreign exchange that may otherwise be required for importing new gins.
6. Ginning factories having single roller gins may derive benefit by converting the bush-bearings of their gins to ball-bearings, as this would result in a considerable saving of power.
7. Each ginning factory or a group of them, depending on the size of the factory, should secure the services of a full-fledged gin engineer. The ginning should not be left in the hands of illiterate and untrained gin fitters as is being done at present. The training course for gin fitters instituted at the Technological Laboratory of the Indian Central Cotton Committee is very useful and the industry should take full advantage of the facilities offered.
8. Factory inspection should be maintained not only to prevent the malpractices followed, but also to give technical advice to the ginning establishments to improve the quality of the ginned lint.
9. Organized marketing facilities for ginned lint and seeds should be provided wherever possible.
10. Proper transport and ware-housing facilities should be provided, the ware-house certificate serving as a negotiable instruments for obtaining credit.

11. Factory laws may have to be suitably amended, if possible, to meet the needs of the ginning factories, which work only during a part of the year; alternatively, power and labour available at the factory should be put to some other gainful employment during the off-season.

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CHAPTER III

MARKETING

INTRODUCTION

Marketing plays an important role in determining the success or failure of any economic enterprise. The productive effort becomes ineffective, if the goods produced do not find their way to those who need them. The process of marketing includes the activities of all persons engaged in transferring goods from the producer to the consumer through various channels.

The principal services included in the marketing process are the following :

1. Assembling — The commodity must be collected from the producer and assembled in bulk, so that the subsequent processes may be cheaply and effectively carried out on a large scale.
2. Grading — The commodity produced must be sorted out into grades of different quality or into classes prescribed to satisfy different types of consumers.
3. Processing — The raw commodity produced on the farm often needs processing and manufacture before being supplied to the consumer.
4. Storing — The commodity must be stored in adequate quantities in order to ensure a regular supply throughout the year.
5. Risk covering — Someone must be prepared to bear the risk of price fluctuations between the time when the commodity leaves the producer and the time that it reaches the consumer.
6. Transportation — The commodity must be transported from the place of assembly to that of final sale.
7. Distribution — Arrangements must be made for the actual sale to the consumer.

These services are performed by a number of agencies, each of them often specialising in a particular task. Efficient marketing reduces the period between the production and consumption of a commodity as well as the cost of the marketing processes. The services of modern marketing are often regarded as parasitic on the ground that the sub-division of functions has been carried too far, unnecessarily lengthening the period between production and consumption, and increasing the cost of distribution, thereby making the commodity and its products more costly. It must not, however, be forgotten that most of these services are essential to the successful marketing of the commodity and that the rendering of these services is much more difficult and complex than is commonly believed.

HISTORY AND DEVELOPMENT OF COTTON MARKETS IN INDIA

From time immemorial, India has been known for its cotton fabrics, The fame of quality fabrics produced in India attracted many foreigners particularly from the West. The following excerpt indicates how important cotton is in India's economy:

> "The history of cotton and textiles is not only the history of the growth of modern industry in India but in a sense it might be considered the history of India during the past one hundred years. The British policy which dominated India during this period circled round cotton to a large extent .... when I think of textiles my mind runs back some thousands of years to the period when India perhaps was the only country producing these textiles and exporting them to distant lands."*

In the second half of the 17th century, the East India Company came to this country in search of Indian calico, silk and Dacca muslin. The policy of the company then was to permit "the utmost latitude to weavers of cotton and silk with a view to encouraging manufacturers." A century after this the Industrial Revolution and the inventions of Hargreaves and Arkwright, which laid the foundation of the textile industry in Great Britain, had their impact on India's cotton textile industry. The policy then followed by the East India Company was to discourage the manufacture of fabrics and make India a supplier of raw material. Thus, the strangulation of the Indian cotton textile industry commenced. The gear was reversed and the internal demand for raw cotton gave way to demand for this material from Great Britain, and India gradually became "a field for the produce of crude materials subservient to the manufacturers of Great Britain."

In the days of regional self-sufficiency, the marketing of cotton was simple. There were no cotton-exchanges, no ginning and pressing factories and no railways. The seed was separated from the *kapas* in the villages by means of *Charkhas* and the ginned cotton was transported over long distances from Berar to Bengal, which was then well-known for the manufacture of cotton fabrics. With the development of foreign demand, cotton from Berar and Gujerat started moving to ports like Bombay, Khambhat (Cambay), Kumpta, etc., which were the outlets for export to Great Britain. For feeding the new textile mills at Manchester, seed cotton used to be collected at suitable centres, ginned by hand and the lint moved to the ports for shipment to Great Britain.

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* Quoted from the foreword by Shri Jawaharlal Nehru written for the book "Hundred Years of Cotton" by Prof. M. L. Dantwala in 1947.

The marketing conditions of about a century back are well depicted in the following extract from a Memorandum dated the 19th January, 1865, on the cotton fields of Nagpur by Mr. Forbes, who was then the Cotton Commissioner for Bombay.

> "The chief cotton marts visited during this tour were Hingunghat, Undoree, Deolee, Anjee and Arvee. Of these Hingunghat is the most extensive and its town is, I believe, the most populous in the Wardah district. The appearance which the 'cotton *gunge*' presented was most striking and quite novel to me. From a distance the enormous piles of cotton heaped up to a point resembled an encampment of tents. These occupy a clear open space outside the town; each merchant's yard having its own enclosure, inside of which is the shed, and in this shed crowds of women are occupied with the *charka*, separating the wool from the seed.
>
> The *charka* used here is smaller than I have elsewhere seen. The rollers both of which are made of *khair* wood, and about ten inches in length, slope towards one end; the machine is worked by one person only; and a woman earns from four to five annas per day, turning out on an average from 6 to 7 lb. of clean cotton; payment is made in coin. .
>
> The market or weighing place, is surrounded by tiers of cotton packages; they cannot be called *dokras* or bales. These packages contain the cotton which has been cleaned in the outlying villages and which is brought in by Marwarees and others for sale or delivery to the cotton merchants. The method of packing the cotton for conveyance affords a striking illustration of the utter indifference that exists on the part of the people towards preserving their fine cotton, either from waste by the way, or from contact with dust and dirt of every description. A coarse net bag of hemp rope is the receptacle; these meshes vary from two to four, or even eight inches square, the cotton is trodden into it, and, of course, projects prominently through these meshes, and on its journey to market it is not only perfectly open to dust and moisture, but it is also subject to heavy contributions by every tree, bush or twig that may happen to come in contact with it. I have repeatedly seen iumps of cotton which had been drawn in this manner strewing the road. At and around the neighbouring stand there was mixture of dust and pulverised cowdung several inches deep over which these cotton bundles were carelessly rolled until they became of a colour that made it difficult from a little distance to say what they contained. The actual loss from waste and the deterioration in value, caused by this careless mode of packing cannot be less than 15 to 12 per cent.; yet, I fear, it will be a work of time to induce the village people to adopt any other mode of sending their cotton to market. Something, however, might be done to obviate the damage the cotton is exposed to on the spot, by having the whole of the cotton mart laid down with shingle, or paved with round stones, as I observed done at other places. A proper weighing machine, such as that used at railway stations, would also be an improvement upon the present primitive article, which consists of a rough beam suspended by a rope with a hook at one end and a basket at the other, stones being used as weights. This article not only gives rise to great waste of time in the operation of weighing, but it was said on the spot that the men who were employed on this duty had it in their power to favour the buyer or the seller to the extent of half a maund or more on each package. Cotton here was brought and sold by the *boja* of twelve maunds, each maund of ten and a half seers (or 21 lb). It was mostly being sent to Mulkapore. An average cart-load was five *bojas*, and a hire of a cart was 45 rupees. The *dokra* here is called *uka*; two go to a *boja*; and each, as packed for the Bombay market, weighs about 137 lb. Gunny bags are used for this final packing here, as elsewhere; but the operation was carelessly performed, and the seems of the bags were left so open that in the transit cotton might be abstracted and rubbish introduced without difficulty."

The above picture reveals that the system of marketing at the time was poor, slow and costly. The British interests, therefore, made strenuous efforts to adapt the prevailing system of cotton marketing to suit the needs of cotton exports to Manchester. The shift from domestic to foreign demand consequently gave rise to new problems of marketing, namely, the evolution of wholesale markets, the improvement in ginning and pressing of cotton and the development of transport. The development of processing and transport received particular attention of the British. Until the middle of the 19th century, the dominant form of transport was the bullock and deliveries at Bombay were contracted in terms of bullock loads of cotton. Speedier transport came into existence only in the late forties of the 19th century. The first railway was constructed in 1853 and by the sixties of the nineteenth century some of the cotton areas in Gujerat and Berar were connected by rail. With the development of railways, many new cotton markets (*gunjs*) sprang up. The power ginning and pressing machinery was also introduced during this period. As a result of these developments and increased production of raw cotton, there are now about 2,500 ginning factories in the cotton producing areas and over 500 important cotton markets are connected by rail with the terminal market at Bombay.

With the growth of the foreign trade in cotton, the need for organising the trading community also became important. The first collective action by the Indian cotton merchants was the formation of a Cotton Dealers' Managing Committee some time prior to 1855. The main function of this association was to discuss problems affecting their trade. The association also took steps to abolish payment in kind which was then customary and to substitute cash allowances in its place. The association further decided to impose a *laga* (cess) on the cotton imported into Bombay and prescribed a detailed procedure for administration of the fund thus collected.

The Bombay Cotton Exchange was formed by some leading merchants of Bombay in 1890. Between 1892 and 1917, several other trade associations representing various interests came into existence. However, the control of the cotton trade during this period was exercised largely by the Bombay Cotton Exchange and the Bombay Cotton Trade Association, the latter of which had been formed in 1875 by the European firms in Bombay engaged in cotton trade.

Another important development of the last century was the phenomenal growth of the Indian textile industry. In 1955, there were 408 spinning and composite spinning and weaving mills, having about 12 million spindles and over two lakh looms. The handloom industry also has made considerable progress in recent years. The result is that over 96 per cent. of Indian cotton is now retained in the country for consumption by the local mills and handlooms. India has thus once again become a manufacturer of cotton goods instead of being merely a producer and exporter of raw cotton.

TYPES OF TRANSACTIONS

The outstanding fact in modern marketing is that goods are sometimes marketed even before they are produced and sometimes stocked for long periods before being sold. The cotton piece-goods sold by the mills today were manufactured long ago and the goods being manufactured currently will be available for sale many months later. In order to maintain the smooth and continuous flow of production, the mills make advance commitments for the purchase of raw cotton and the merchants enter into contracts to sell it to them even before the cotton is actually harvested.

This time element in the production process makes it necessary to distinguish between spot or ready transactions, on the one hand, and forward transactions, on the other. The basis of the distinction is the period that passes between the signing of the contract and the delivery of the commodity. Under spot or ready contracts, the delivery has to be made immediately or within a specified number of days. When delivery is contemplated after a longer period of time, the contracts are called forward contracts.]

READY MARKETING

Sowing, Harvesting and Marketing Seasons. Owing to varying soil and climatic conditions of the different cotton tracts and the differing maturation habits of the varieties grown, the sowing and harvesting seasons vary from tract to tract. Taking the country as a whole, the sowing season extends from April to November, and harvesting takes place all throughout the year. As a result of the long picking period, the marketing season lasts from October to August. There is a cotton crop ready for sale practically throughout the year. The bulk of the crop, however, moves into the markets between October and May. The normal sowing, picking and marketing seasons of the different commercial cottons grown in the country are shown in Table 21.

Assembling. Unlike the practice in the United States, in India cotton is sold by producers usually in the form of *kapas* (seed cotton). Only negligible quantities are sold as lint. The *kapas* is sold by the producers either in the village itself or in the nearby *mandi*. In the primary markets in the villages, the assembling is done by the petty village merchants and itinerant dealers. In some areas the agents of the ginning factories also visit the villages and make purchases of *kapas*.

Disposal of crop in the villages constitutes the predominant practice in many States. In Madras State, it is estimated that about two-thirds of the total production is sold by the cultivators in the villages, while in Mysore 80 per cent. of local production is assembled by the village or itinerant merchants. In the Punjab, in the northern districts of Amritsar, Jullundur and Ludhiana, where the holdings are relatively small, about 85 per cent. of the produce is reported to be sold in villages, while in the western districts, where the holdings are large, more than 90 per cent. of the produce is brought to the local wholesale markets (secondary markets) by the producers themselves.

TABLE 21. SOWING, PICKING AND MARKETING SEASONS OF COMMERCIAL COTTONS

Variety	Sowing season	Picking season	Marketing season
Bengals	April to June	September to January	October to July
Punjab-Americans	April to June	October to January	October to July
Buri	June	November to January	December to June
Oomras	June to July	October to January	October to August
Hyderabad Gaorani	June	October to December	November to August
Broach	June to July	January to April	February to July
Surti	June to July	December to March	March to July
Dholleras	July to August	January to April	January to August
Kumptas	August to September	March to May	April to August
Westerns	August to September	February to April	January to August
White and Red Northerns	June to October	February to April	January to August
Warangal and Cocanadas	July to September	January to April	February to August
Tinnevellies and Karungannies	October to December	March to August	April to December
Cambodias	September to October	April to July	May to January
Salems	September to October	April to July	April to November
Comillas	May	October to December	November to August
Dharwar-American	August to September	February to April	October to July

The system of assembling of *kapas* in the Gujerat area of Bombay State differs from that prevalent in other parts of the country. In south and middle Gujerat, the *kapas* is sold mostly to the agents of the ginning factories who move about in the villages during the cotton season. Appreciable quantities, nearly 40 per cent. of the production of that area, are also assembled by cotton co-operative societies, who set up their offices during the season at important ginning factories.

The system of village sales though convenient in some ways, causes an appreciable loss to the seller. Due to lack of up-to-date market information, use of faulty weights, the unscrupulous methods of village merchants, and the indebtedness of the farmer, the producer of cotton usually receives a low price.

In the secondary markets—the *mandies* or *gunjs*—which are the assembling and distributing centres, *kapas* is brought in carts or in some areas even waded on pack animals. The use of motor trucks for transporting *kapas* from villages to the *mandi* centres has not yet become popular. The carts are parked at the open space which is reserved for the use of the cotton market. In many places, the compounds of the ginning factories are used for the purpose. The prospective buyers, *dalals* and *adatyas* move about in the market examining the quality of the arrivals. At some places, such as Adoni (Andhra Pradesh), the samples are drawn from the carts by *dalals* who go from shop to shop and canvas the orders. The buyers in the wholesale markets are generally *pucca adatyas*, who buy on behalf of their clients in far-off centres, and the agents of cotton firms at Bombay or of textile mills. Recently there has been a tendency on the part of the textile mills to purchase raw cotton directly in the assembling markets. After the bargains are made, the carts are taken to the local ginneries where the *kapas* is weighed and delivered to the purchaser. In some cases, delivery is given in the market yard itself and the buyers arrange to transport the *kapas* to the ginneries. The survey made by the Deshmukh Cotton Marketing Committee (1951) revealed that in 90 per cent. of the cases *kapas* is weighed and delivered at the ginning factories.

Prices are settled either by auction or by negotiations, open or secret. In almost all the regulated markets and in some of the unregulated ones, the system of open auction of *kapas* is in vogue. This is, no doubt the best method of securing a competitive price but where the numbr of buyers is not sufficiently large, they jointly agree not to bid beyond a certain limit, thereby defeating the very idea of a competitive market. In some markets of the Marathwada Division of Bombay State where the daily arrivals exceed 1,000 carts, a different system of auction, known as *fardi*, is practised. Under this system, the total number of commission agents in the markets is divided into as many groups as the number of days in a week and each group is allotted a day by rotation. The auction is done in the absence of the commodity. Everyday the total quantity of *kapas* received by the commission agents composing the group to which the particular day is assigned, is put up for auction and it is obligatory for the highest bidder to purchase the entire lot. The highest price quoted in the auction becomes the ruling price of the day and the other groups sell their cotton on the basis of this price to buyers of their choice. The *fardi* system no doubt expedites the marketing and disposal of heavy arrivals of cotton, but it is not free from defects. Fixation of price in the absence of the commodity often leads to disputes due to differences in the quality of cotton eventually delivered.

In some of the markets, prices are settled by negotiations between the *adatyas* of the sellers and the buyers or their commission agents. Though the seller is usually consulted by his *kachcha adatya* before the bargain is finalised the cultivators have in fact little voice in the settlement of prices. In some markets, the price of *kapas* is settled secretly (*hatta system*) by pressing the fingers of the hand in different ways under cover of a piece of cloth. Under this system, only the commission agent who receives the offers is in the know of the various bids. Though this system is claimed to secure better prices, the secrecy under which the bids are made leads to suspicion in the minds of both the buyers and the sellers. It also gives scope to the commission agents to favour any party and accept any bid. For the benefit of the producers, the fixation of price by open auction is desirable and needs to be introduced in all the markets.

The business in the up-country markets is not transacted on the basis of any contract terms. Lack of standards for quality and refraction results in many disputes between the sellers and the buyers at the time of actual delivery. Except in regulated markets, there are no arrangements for settling disputes in assembling centres.

Ginning and Pressing. Before the cotton is moved to distant consuming centres, the *kapas* is ginned and the lint pressed. The ginning is arranged by the buyers either in their own ginning factories or in other factories owned by private concerns, on payment of the usual charges. In Gujerat and some parts of Madras, co-operative ginning and pressing factories have been set up for processing the cotton of the members of the Co-operative Cotton Sale Societies.

There are about 2,500 ginning factories in the Indian Union. Nearly 40 to 45 per cent. of them remain idle and many of the other factories work only for part of the season. Since cotton ginning is only a seasonal affair, a large number of factories has been equipped with oil crushing or rice milling machinery in addition. Some of the ginning factories have also installed cotton presses. About 75 per cent. of the gins are of the single roller type and the remaining 25 per cent. are double roller gins. A recent enquiry conducted by the Indian Central Cotton Committee revealed that 35 per cent. of the ginning factories have less than 10 units each, and 53 per cent., less than 20 units. Very few factories have an equipment for the opening and cleaning of *kapas* . In more than half of the factories, the machinery is over 50 years' old and steam is the common motive power. The charges for ginning vary widely both within a State and between different States, and these generally range from Rs. 8 to Rs. 15 per bale of ginned cotton. The number of pressing factories in the country is over 900. Pressing charges vary from Rs. 7 to Rs. 12 in different States. The ginning and pressing charges are comparatively higher in the Punjab. In the marketing of cotton, ginning and pressing charges form a substantial part of marketing costs. To reduce the cost of processing, it is imperative that the efficiency of the ginning and pressing factories be improved.

The excessive number of ginning factories has made ginning uneconomical. Therefore, in many parts of the country, ginning pools are formed to eliminate competition and make ginning a paying proposition. The net profits of the working factories are shared by all the members of the pool. However, the ginning and pressing charges fixed by such pools are usually excessive, and they cut seriously into the earning of the cotton growers.

In all the cotton growing States, Cotton Ginning and Pressing Factories Act has been passed and enforced. This Act provides for the licensing of the factories and prescribes that the owners of each ginning and pressing factory shall maintain a record of all cotton processed by it and of the names of persons on account of whom the cotton is ginned and/or pressed. The Act also lays down that each bale shall be marked in the prescribed manner with the serial number and the mark assigned to the factory. The press-owners are further required to submit a weekly report of the total number of bales pressed.

Several malpractices commonly associated with the ginning and pressing of cotton in the past are now on the wane. Watering and false packing of cotton are much less prevalent than before. Mixing of inferior varieties of cotton with superior varietis, however, is still common in some localities, although the law prohibits such mixing. To maintain the purity of cotton grown in a tract the Cotton Transport Act is in operation in several States. Under this Act, zones for different improved varieties are prescribed and transport of the produce of any other varieties into the zone, or from one zone to another is prohibited.

Although the Cotton Ginning and Pressing Factories Act and the Cotton Transport Act have been enforced by all the important cotton growing States, adequate check is not exercised on the working of ginning and pressing factories with the result that some of the malpractices still go undetected.

Distribution. After Cotton is ginned and pressed, it is moved from the assembling centres to the consuming centres. In the secondary markets, the distribution of cotton is done by the merchants and gin-owners and also by the agents of the exporting firms and the textile mills. At the consuming centres, a large number of merchants and commission agents operate and arrange for supply of cotton from the up-country markets to the local textile mills or the exporting agencies. The commission agents receive cotton on consignment basis, whereas the merchants usually purchase it on their own account. When the cotton is sold on consignment basis, all the expenses incurred on handling, transport, etc., are recovered from the seller or the buyer as the case may be. At Bombay, which is the principal terminal market for cotton, ready sales take place at Sewri (Plate XIII.) The sales are made on sample basis. After the price is settled, the bales concerned are examined by the buyer and samples weighing 10 to 15 lb. each are drawn according to a prescribed method from two per cent. of the bales purchased. The purchases at Bombay are made on the basis of the contract terms prescribed by the East India Cotton Association. In Surat, purchases by the textile mills or the shippers are made according to the contract terms laid down by the Surat Cotton Dealers' Association. Some of the textile mills have also their own contract terms on the basis of which they make purchases in the up-country markets. At Bombay, arbitration facilities are provided by the East India Cotton Association. If the cotton purchased is not found to be up to the quality contracted for, the dispute is referred to the Association's surveyors who examine the bales or the samples and determine the 'on or 'off' allowances to be paid by the seller or the buyer.

On the partition of the country in 1947, the supply of over a million bales of good quality cotton, formerly contributed by the areas constituting Pakistan, was discontinued. This diminution of supplies necessitated governmental control on the distribution of local production. Accordingly, a Cotton Control Order was issued in September, 1949, to regulate, *inter alia*, the distribution of cotton throughout the country. This order was amended in 1950 and from time to time thereafter giving wider powers of control to the Government. In 1955, a new Cotton Control Order was issued under Section 3 of the Essential Commodities Act (X of 1955), superseding all previous Orders on this subject. Under the New Order, the Textile Commissioner of the Government of India was empowered to prohibit the transport of cotton from any place within a specified area to any place outside it except under such conditions, limitations and restrictions as he might specify. He is also empowered to direct any carrier to close the booking and transport of any cotton or *kapas* by rail, road, water or air between such places and for such periods as he might specify. Necessary orders for regulating the distribution of the commodity between the different parts of the country have been issued periodically by the Textile Commissioner.

Finance of Marketing. The production of cotton by the farmers requires finance. The sources from where the cotton cultivator gets his credit are the local money lenders, the middlemen, *adatya* and gin-owners and the co-operatives. The bulk of the credit is supplied by the local money lenders. The Committee of Direction of the Reserve Bank of India in their report on the All Indian Rural Credit Survey estimated that 45 per cent. of the total credit requirements of the cultivators is supplied by the money lenders while the co-operatives supply only about three per cent. of the funds needed. The local money lender advances loans for all purposes and charges rates of interest varying from 12 to 15 per cent., depending on the credit-worthiness of the borrower. The middlemen advance money to the farmers just before the harvest time with a view to securing business. They, generally, do not charge any interest, and though there is no legal obligation, the farmer is morally bound to sell his crop through his financier. In Gujerat, gin-owners, who are also cotton merchants, finance the cultivators to a considerable extent.

Financing of the internal trade in cotton is done by the local merchants, the up-country agencies of the firms at Bombay and banking organisations. The up-country merchants and even the gin-owners who themselves trade in cotton, sometimes advance money to the itinerant traders who agree to sell the *kapas* through them. The big Bombay merchants sometimes finance the merchants in the up-country markets. The banks advance money to the extent of 60 to 70 per cent. of the value of the goods deposited in their godowns. The indigenous bankers, namely, the *savkars*, also play an important part in the financing of the internal trade. In their case, elaborate formalities are not required to get the loan ; *hundi* is the chief instrument of transaction.

Grading and Standardisation. Grading cotton of on the basis of the purity of variety is of recent origin in India and is being done in some of the interior markets under the Agricultural Produce (Grading and Marketing) Act, 1937. As the spread of improved varieties of cotton centres round better marketing, the Government of India at the instance of the Indian Central Cotton Committee included cotton in the schedule framed under the said Act.

Two grade specifications, viz., 'Agmark certified pedigreed' and 'Agmark certified' have been prescribed for each variety. The grade specifications are based mainly on the purity of cotton, at least 98 per cent. for the first grade and 97 per cent. for the second. The purity of produce depends on the purity of the crop in the field and the elimination of admixture in processing. The examination of the crop in the field and the check inspection of the ginning and pressing processes by the appropriate Government Department, therefore, constitute the basic procedure for grading. The grade specifications also provide that the lint shall be obtained from machine ginned *kapas*, that it shall be dry and free from any trace of added moisture and that it shall be clean and reasonably free from leaf trash, seed and other impurities. The bales graded in accordance with these specifications are affixed with an 'Agmark' ('Ag' for Agricultural and 'mark' for marketing) label showing variety, grade and place of production. The label is the guarantee of the *purity* of the produce graded.

The Agmark grading of cotton was first undertaken in 1941 in the Surat area for the 1027 A L. F. variety. Since then, it has been extended to other varieties, viz., (*i*) Kalyan (North Gujerat), Vijalpa (2087) (South Gujerat), (*ii*) Vijay and Digvijay (Middle Gujerat), (*iii*) Virnar (Khandesh), (*iv*) Laxmi (Hubli-Dharwar), and (*v*) Punjab-American varieties 320F and 216F.

The quantities of cotton of all varieties graded under Agmark during the three years 1954 to 1956 are shown in Table 22.

TABLE 22. QUANTITY OF COTTON GRADED UNDER AGMARK

Year	Quantity graded (bales)	Percentage of the total Indian production	Value (thousand rupees)
1953-54	50,316	1·3	21,900
1954-55	1,55,912	3·7	48,749
1955-56	2,52,941	6·2	1,19,471

Though the system of Agmarking cotton covers a small percentage of the total production, it has enabled the growers of pure varieties in the reserved seed multiplication areas to sell their cotton at a premium ranging between Rs. 10 and Rs. 15 per bale. It has also enabled the State Departments of Agriculture to secure the requisite supplies of pure seed of improved varieties. The Agmarking has its limitations also. Even the produce of botanically pure varieties shows minor differences of staple length and strength due to variations in soil, climate and season. Agmark grading, based on purity of crop in the field, takes no account of differences in quality factors which determine the spinning value. As such, the Agmark does not facilitate the picking up of even-running bales of the required spinning value.

Business in cotton in India is, therefore, still transacted on the basis of samples. This method is not only time-consuming but it also often leads to disputes. For efficient marketing of cotton, a standardised system of classing the produce on the basis of fibre properties, that determine the spinning value, is essential. Some standards have, however, been fixed by the East India Cotton Association, Bombay, for purpose of 'futures' trading. Five grades namely, 'Extra Superfine' 'Superfine', 'Fine' (basic grade), 'Fully Good' and 'Good to Fully Good' have been defined for each of the tenderable varieties of cotton. Standards for tenderable staples have also been fixed and standard samples of each grade and staple are prepared by the Association. While these measures help in transacting business in the Bombay market, in quoting 'off' and 'on' allowances over the basic grade and in settling disputes, no system of grading and marketing individual bales in the up-country markets has been adopted so far.

Due to lack of standardised grades of quality, the prices ruling in the up-country markets do not fully reflect the premium paid for superior quality cotton in the terminal market at Bombay. Cotton growers who produce *kapas* of better quality than the average handled in a local market do not receive much more than the growers who produce cotton that is of average or below average quality. The failure of the marketing system to pass on to the growers the price differentials which reflect differences in spinning value adversely affects the producer of superior cotton. It is, therefore, imperative that a proper grading of lint is done at the initial stages. The defect in the existing system can be remedied by providing an impartial and dependable cotton classification service on the lines of that in the United States. In that country a free grading and classing service for farmers was initiated in 1937 with the passage of the 'Smith Doxey Act.' This Act has provided for the free classing of cotton for the members of the cotton improvement groups, especially the farmers, and for collection and dessimination of grade-wise cotton market prices. Accordingly, the American farmers are now usually aware of the prices they should expect in their nearest market for the class of cotton produced by them.

With a view to prescribing grade specifications on the basis of staple length and other fibre characters which determine the spinning value of cotton, a pilot scheme is being operated by the Directorate of Marketing and Inspection in South Gujerat. Under this scheme, samples of cotton were collected during 1956-57 cotton season from the entire South Gujerat cotton zone and these are being studied in the Technological Laboratory of the Indian Central

Cotton Committee for determining the quality characters for framing tentative grade specifications.

Regulation of Markets. Owing to the defects enumerated above, the wholesale markets generally operate in an atmosphere of uncertainty and suspicion. The result is that often the producer of cotton does not get a fair deal. The existing conditions are also not conductive to a proper development of the cotton economy.

With a view to improving trading conditions in the interior markets, the need for establishing regulated cotton markets was recognised as early as in 1886, when the first such market was set up at Karanja under an order of the British Residency at Hyderabad. Thereafter, the 'Berar Cotton and Grain Markets Law' was passed in 1897 and cotton markets in Berar were regulated. Later, the Government of Bombay, at the recommendation of the Cotton Committee appointed by the Government of India in 1919 passed the 'Bombay Cotton Market Act' incorporating suitable provisions for removing the defects that existed in the Berar Act. In 1928 the Royal Commission on Agriculture drew pointed attention to deplorable marketing conditions prevailing in the *mandies* and recommended statutory regulation of all markets for agricultural produce on the pattern of the Bombay Act. As a result of these recommendations and those made subsequently in the Commodity Marketing Reports issued by the Directorate of Marketing and Inspection, statutory regulation of markets was taken up in several States. During the period from 1950, regulation of markets was introduced in the States of Bombay (1927), Hyderabad (1930), Central Province (1932), Madras (1933), Punjab (1941), Mysore (1943) and Pepsu (1948). Thus, while in 1930 there were only 25 regulated markets—24 in Berar and one in Bombay—by 1950 the total number rose to 265. The regulation of markets received further impetus when in 1951 the Planning Commission in its First Five-Year Plan recommended that States which had not till then enacted the Markets Acts should pass the necessary legislation and regulate the markets, and in States where Markets Acts were already in operation, they should be extended to all the remaining important markets. As a result of this recommendation, Markets Acts were passed by two more States, namely, Madhya Bharat and Saurashtra. Thus, at the time of the re-organisation of the States in November, 1956, Markets Acts, were in force in ten States, and the number of regulated markets was 522; Andhra Pradesh (78), Bombay (186), Madras (19), Madhya Pradesh (74), Mysore (48), Punjab (115) and Kerala (2). Cotton was handled in over 350 of these markets. In 1954-55, it was estimated that in the seven former States of Andhra, Bombay, Hyderabad, Madras, Mysore, Madhya Pradesh and Pepsu about 26 million maunds of *kapas*, valued at Rs. 61 crores, was sold in the regulated markets. This quantity represented about 62 per cent. of the cotton produced in these States and about 45 per cent. of the total Indian production.

The regulated markets work on democratic principles. For the management of the markets, the State Markets Acts provide for the formation of market committees consisting of representatives of growers, traders and local bodies. In the State of Madras and the Andhra Division of Andhra Pradesh, a market committee is set up not for each market but collectively for all the markets of a district, while in other States a market committee is formed for each market separately. The number of members of a market committee varies from 12 to 16, at least half of which are growers' representatives who are either elected or nominated by the State Government. The remaining members consist of the elected representatives of the traders and the nominees of the local bodies and the Government. The committees are autonomous bodies. For their proper functioning, they frame bye-laws in consonance with the Act and Rules defining the local market practices and the market charges payable to the various functionaries assisting in the disposal of produce assembled at the market. The market functionaries, such as commission agents, brokers, weighmen, etc., are licensed by the market committee. Each market committee also appoints a Disputes Committee for settling disputes arising between buyers and sellers.

Kapas is assembled at the market yard where the auctions are conducted in the presence of the staff of the market committee. The weighment and delivery of *kapas* are made at the premises of the buyers, i.e., the ginning factories. The weighment is done by the licensed weighmen who are not employees of the buyers or the commission agents. A check on weighment is also exercised by the Committee. Use of standard weights is insisted upon and periodical inspection and verification of scales and weights is carried out by the market committees' staff. The licensed commission agents issue *tak pati* (sales memo) to the sellers, showing the particulars of the sale proceeds and the deductions on account of commission, weighment and other charges authorised by the Committee. Prior to regulation of markets, credit sales were common and accounts were settled by the commission agents at a later date. In the regulated markets, payment on the day of the sale is insisted upon. The committees also make arrangements for dissemination of market information.

The regulation of markets has conferred many social and economic benefits upon the producers. Several malpractices, such as short weights, *hatta* system of sale and deduction of unauthorised market charges, have been done away with. Selling by open auction has been introduced. The market charges paid directly by the producers have been reduced by 29 to 69 per cent. of pre-regulation charges in different States. The 'Expert Committee' appointed by the Government of Bombay in 1954 to review the working of the Bombay Agricultural Produce Markets Act estimated that due to reduction of market charges alone the producer saves Rs. 3 for every Rs. 100 worth of produce sold by him in the regulated markets. Furthermore, the regulated markets in many localities have provided market yards with facilities for parking of carts (Plate XIV), temporary storage of produce, and such other amenities as drinking water, cattle sheds, rest houses for the producers, libraries, etc.

The producers in the areas served by the regulated markets have shaken off their traditional indifference and developed a proper market sense. Whereas formerly 90 per cent. or more of the total arrivals was brought to the markets by the village merchants or petty dealers, now only 40 to 60 per cent. is handled by them. The mutual distrust between the sellers and the buyers is also gradually disappearing. The influence of the regulated markets on prices is difficult to assess, but it can safely be asserted that the regulated markets provide an atmosphere for fair and healthy competition which generally results in higher net returns to the seller.

Though the regulation of markets has exercised a wholesome influence on the marketing structure and brought about considerable improvement in marketing practices, adequate protection for the numerous small growers still remains to be secured. This is due to the fact that a large number of markets continue to remain outside the regulatory orbit and nearly 55 per cent. of the cotton produced in the country is sold in unregulated markets or in the villages, where the old practices which are not in the interest of the producers, continue unchanged. It may also be mentioned that the business community has been rather slow to submit to the discipline imposed on it by the market legislation. There have been several instances where the traders have challenged the validity of the Markets Acts in the courts.

Co-operative Marketing. The application of the co-operative principle to marketing of agricultural commodities was first recognised in India when the Co-operative Societies Act, 1912, provided, among other things, for the organisation of non-credit limited liability societies. Five years thereafter, a Co-operative Cotton Sale Society was set up at Gadag in the Karnatak area of Bombay Presidency (now in Mysore State). The main object of this society was to popularise improved varieties of cotton by distributing pure seed to the grower-members and to sell their cotton at the highest possible rates. Co-operative marketing of cotton is now carried out in the reorganised States of Bombay, Madras, Mysore and the Punjab. In Bombay and Madras, co-operative ginning and pressing societies have also been established. The majority of the co-operative cotton sale societies are single commodity societies, working on a commission basis. The co-operatives in Gujerat and Vidarbha Divisions of Bombay and Dharwar district of Mysore have made substantial progress. A brief description of their working is given below.

The number of primary cotton sale societies in Gujerat is about 86 and of the ginning and pressing nearly 26, the latter being located mostly in South Gujerat. The majority of the societies in South Gujerat are affiliated to the Shree Daxin Gujerat Sahkari Cotton Marketing Union, Ltd. The management of the sale societies is strictly democratic in character in as much as it is entirely in the hands of members belonging to the cultivating class. The noteworthy feature of the Gujerat societies is that the produce of the members is pooled and sold after it has been ginned and pressed in the co-operative factories of which the primary societies are also members. Sales of the pressed lint are generally arranged through the Union at Surat. The Union sells the lint by private treaty. The entire sale proceeds of the season after deducting the actual expenses incurred in ginning, pressing, transport, insurance, etc., are distributed *pro rata* among the members. The price paid per unit is the same for every member. The societies also arrange for grading of cotton on the 'Agmark' basis. Loans at 6¼ per cent. interest are advanced by the primary societies up to 75 per cent. of the value of the produce actually handed over by the members. The loans are adjusted at the time of the final settlement. According to the bye-laws of the societies, it is obligatory on a member to sell his cotton through the society, failing which a penalty of Rs. 50 to Rs. 100 is imposed. Table 23 below indicates the progress made by the co-operative societies in South Gujerat.

TABLE 23. PROGRESS IN THE SALE OF COTTON THROUGH CO-OPERATIVE SOCIETIES

Year	Number of societies working	Total membership	Total crop of the area (bales)	Number of bales sold through co-operatives	Percentage of the total crop marketed through co-operatives
1952	44	14,169	94,052	19,306	20·5
1953	42	15,049	1,27,301	29,317	23·2
1954	45	16,619	1,70,000	50,429	29·6
1955	43	21,792	2,08,552	69,771	33·0
1956	52	25,000	2,53,000	1,05,000	41·5

In an *ad hoc* survey conducted in 1950 on the working of the co-operative societies in Gujerat, it was estimated that by selling through the co-operative societies cultivators realised Rs. 15 more per *bhar* (924 lb.) of *kapas* than they would have realised by selling directly. Over 73 per cent. of this additional income was contributed by the grading of lint and the sale of improved seed at a premium, the remainder being ascribed to pooling, co-operative ginning and other attendant benefits.

Co-operative marketing of cotton in Karnatak area is concentrated in Dharwar district. The pattern followed here differs very much from that followed in Gujerat. The societies in Karnatak do not pool their produce or get it ginned before sale. The *kapas* brought by the members is auctioned directly by the societies. Auctions are conducted at intervals of a fortnight or so and the *kapas* assembled during this period is graded into five lots and according to the ginning outturn, varying between 35.5 and 37.5 per cent., and the stage of multiplication of pure seed. The cultivators are paid the actual auction price of the grade, less the commission of the society. Profits, if any, are distributed *pro rata* at the close of the season. Unlike the case in Gujerat, it is not obligatory for the members to sell their cotton through their society. In Karnatak, the improved seeds are distributed only through the societies while in Gujerat, such distribution is done both through co-operatives and private agencies.

The marketing of improved varieties of cotton in the Vidarbha Division of Bombay State is organised by the Vidarbha Marketing Society under the 'Cotton Pool Scheme'. The Taluka Agricultural Associations affiliated to this apex organisation work as agents for pooling the produce of improved varieties of cotton at selected centres. The Taluka Associations are also the agents of the Government Department of Agriculture for distribution of pure seed of improved types. The Marketing Society arranges the sale of pooled cotton by auction and charges a commission of Rs. 1.50 per candy.* Two-thirds of the income from this source is allotted to the Taluka Associations. By selling their cotton through the society, the producers of improved varieties generally realise Rs. 15 to Rs. 20 more per candy.

As a result of the policy of the Government of India to issue licenses for export of cotton to co-operative societies, some of the societies have recently taken to exporting cotton. In 1955-56, three societies in Bombay and the Vidarbha Marketing Society were allotted export quotas of 35,000 and 33,000 bales, respectively. The export is generally arranged by the societies through the agents appointed by them at Bombay. The societies now earn a sizeable profit from this business also.

FORWARD MARKETING

Delivery Contracts and Hedge Contracts. As mentioned already, 'forward' marketing differs from 'spot' or 'ready' trading in that delivery under 'forward' contracts is contemplated after a long period of time. Forward contracts are of three types, viz., non-transferable specific delivery contracts and hedge or futures contracts. The first two types of contracts are together referred to as delivery contracts. The principal differences in these three contracts arise out of the condition of delivery and the mode of settlement. In non-transferable specific delivery contracts, the buyers and sellers agree on the quantity, the quality, the price, the date of delivery and the place of delivery. The contracts, therefore, are similar to ready contracts except in that the delivery takes place after a longer period. In the case of transferable specific delivery contracts, the documents of title being transferable, delivery takes place between the first seller and the last buyer. The contracts, however have to conform to the same detailed specifications as in the case of non-transferable specific delivery contracts. The hedge or futures contracts, on the other hand, are contracts entered into in terms of a basis quality and do not visualize actual delivery at all, except in a residual sense.

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* I candy=784 lb.

The settlement in the non-transferable specific delivery contracts takes place through the payment of the actual value of the goods by the buyer to the seller, whereas the futures contracts and the transferable specific delivery contracts in so far as the intermediate buyers and sellers are concerned are settled by the payment of the difference.

The main function of delivery contracts is to enable sellers to merchandise their goods over time. The hedge or futures contracts, on the other hand, enable the merchants to protect themselves against the risk of price fluctuations.

Need for Hedging. Trading in commodities over a long time involves exposure to constantly fluctuating prices. The mills that buy raw materials or manufacture goods in advance and the merchants who agree to sell cotton at a distant date must store them over a considerable time, during which changes may occur in prices to wipe out the manufacturing or marketing profits. This occasions the need for hedging.

Technique of Hedging. The technique of hedging is simple. The dealer enters into a contract to sell or purchase a commodity in the futures market against a previous purchase or sale of about an equal quantity in the ready market, with the expectation that the losses from fluctuations in the price of the commodity in one market will be mostly off-set by the gains from fluctuations in the other market. Thus buying or selling risks in the ready market are neutralised or hedged by selling or buying futures. In both cases, there are actual transactions in the goods which off-set the futures transactions.

The practice of hedging is based on the assumption that the ready price of the commodity and the price of the futures contract in it will advance, or decline together. The ready and futures prices ordinarily do move in sympathy with each other, because they are subject to the same fundamental economic forces. To the extent that they do not move together, hedging does not protect the operator from price fluctuations.

Role of Speculators. Hedging enables persons to transfer the risk from themselves to others who are willing to assume it in the hope of making a profit from the very price changes which the hedgers wish to avoid. These other persons are speculators. They sell or buy futures contracts without any corresponding transactions in the ready market. The professional speclators assure the market of a balance in purchases and sales. When a transaction takes place for future delivery, it may well be that it is between two genuine hedgers or two professional speculators or between a hedger and a speculator.

Characteristics of a Hedge Contract. The principal characteristics of a hedge or futures contract are as follows :

Standard Contract : It is a standard contract, subject to the rules and bye-laws of an organised association and applicable to all the members of the association. The unit of trading, the terms and months of delivery, the terms of payment and the penalties for non-fulfilment, etc., are prescribed by rules.

Basis Contract : It is a basis contract in the sense that only one specific grade, representative of the commodity, is mentioned in the contract, though certain other specific grades are also made tenderable by the seller. If the seller tenders a grade better than the basis grade, he receives a premium, and if a lower grade, a discount.

Sellers' Option : The seller is given an option regarding the day on which delivery can be made during the delivery month, the grade to be delivered and the place of delivery. The option to choose a suitable day for the purpose of delivery enables the seller to bring stocks from the mofussil areas, if necessary.

Tenderable Varieties : It is open to the seller to tender any one of the many varieties which are tenderable against the contract. The objects of making many varieties tenderable are: (*i*) to reduce the scarcity of tenderable supplies; (*ii*) to provide hedging facilities to as many commercial varieties as possible; and (*iii*) to ensure that the ready and futures markets remain related. If the tenderable varieties cover only a small portion of the crop, the contract might tend to become unduly narrow and the choice to tender might become ineffective. If the choice is too wide, on the other hand, the contract may become too wide and the basis variety might lose its representative character.

Payment of Differences : The premiums and discounts for different varieties over the price of the basis variety are called the 'tendering differences'. Broadly speaking tendering differences are of two kinds, namely, the 'fixed difference' and the 'commercial difference'. The fixed differentials for each grade are determined prior to the commencement of the contract or the season. This system is generally used in respect of those commodities which are more uniform in quality or which can be easily graded. The 'commercial difference' on the other hand, are fixed on the basis of actual selling prices of the different grades existing in the market at the time of delivery. This system or its variant is adopted in respect of commodities like cotton in which there are too many varieties and where it is impossible to gauge accurately the possible price differences in advance. Futures contracts, whether entered into for the purpose of hedging or speculation, are often closed out by off-setting sales or purchases and settled by payment of the difference between the purchase price and sale price. Actual deliveries against futures contracts are small.

Points of Delivery : The delivery is permitted to be given and taken at a number of mofussil centres in addition to the forward market itself. This facility avoids, firstly, undue strain on warehousing accommodation in the forward marketing centre and, secondly, physical transportation of goods from the areas of production to the marketing centre, enabling their despatch directly to the points of consumption.

Dangers of Futures Trading. A forward market tempts persons with insufficient funds and little experience to indulge in large operations through brokers at nominal brokerage charges. When these persons default on their obligations, they not only ruin themselves and their creditors, but also upset the entire market. The professional speculators are also tempted to use their export knowledge and financial resources to manipulate the market to serve their own interests, leading to frequent crises, ending in widespread failures to meet obligations and untold suffering to genuine operators. It is important, therefore, that in the public interest, forward markets should be permitted only under regulation.

Requirements of Commodity to be Traded on a Futures Market. Any commodity traded in a futures market has to satisfy the following principal conditions :

1. It must be available in abundant supply so that it cannot be cornered by a few traders.
2. It must be in continuous demand from a large number of buyers.
3. It should not be quickly perishable.
4. It should be capable of being graded and standarized so as to permit purchase and sale through a standard contract.
5. Its quality should be determinable by tests that yield identical results when applied by different experts.
6. The commodity should be liable to considerable fluctuations in prices.

Cotton is probably the most important commodity in regard to which the technique of futures trading was first used in India. It satisfied all the conditions necessary for a commodity to be traded in a Futures Market. The internal production of Indian cotton ranged between 40 to 50 lakh bales, which was about 11 to 12 per cent. of the total world production. The demand for it was continuous from the mills and the exporters. It was capable of being stored and the storage facilities were adequate. There was in existence an elaborate system of grades and standards based on staple and quality which was universally recognised. The variations in the quality and quantity of the crop from year to year led to price fluctuations of a pronounced character.

History of Futures Markets in Cotton. Futures trading in cotton on an organised basis started with the formation of the Bombay Cotton Trade Association, Ltd., in 1875, at Bombay. This was a joint stock company and practically all its shares were held by Europeans.

About 1890, some leading Indian cotton merchants and millowners, being dissatisfied with the working of the Bombay Cotton Trade Association, started The Bombay Cotton Exchange Ltd. The majority of its shareholders were Indians, but membership was not denied to foreigners and a few foreign merchants were also enrolled.

These two associations shared between them the control of most of the cotton trade, both forward and ready, from 1893 to 1915. Some attempts during the period were also made to broaden the Bombay Cotton Trade Association by admitting a few Indian merchants. The rivalry between the two associations, however, continued much to the dissatisfaction of the genuine traders who had to transact business subject to the rules and regulations of one or the other of the two bodies. In 1915, therefore, a new body called The Bombay Cotton Brokers' Association was formed. This association conducted its morning session of trading at the premises hired by it in the Marwari Bazar and the evening session at Colaba, where much of the ready business was transacted.

The inadequacy of these early efforts became evident when the First World War broke out in 1914 and the trade experienced violent fluctuations in prices. There was then no single representative association in existence, with the requisite authority to enforce its decisions. The hedge contracts were not well-defined and there was no system of periodical settlements. The market was dominated by speculative interests, and experienced severe crises, making it necessary for the Government to intervene. In 1818, the Government issued 'Cotton Contract Rules' under the Defence of India Act and constituted the Cotton Contract Committee under the chairmanship of Sir Gilbert Wiles to regulate the trade in Bombay. The Committee established a clearing house, introduced a system of periodical settlement, licensed the brokers and appointed a daily rates committee to fix and declare the market rates. It also prescribed the forms of contracts, framed rules under which transactions were to be made and provided for the following five hedge contracts : (*i*) Fully Good M. G. Bengal ; (*ii*) Fully Good M. G. Broach ; (*iii*) Fine M. G. Fair Staple Oomra ; (*iv*) Fully Good M. G. Fair Staple Oomra ; and (*v*) Good M. G. Good Staple Southerns.

In 1919, the Government of Bombay enacted the Bombay Cotton Contracts Control (War Provision) Act I and set up under it the Cotton Contract Board in place of the Cotton Contract Committee constituted previously under the Defence of India Rules. The Cotton Contract Board controlled the trade from June 1919 to May 1922. The principal task entrusted to the Board was to explore the possibility of forming a single representative association. The Board framed the Memorandum and Articles of Association for such a central association and it was registered under the name of the 'East India Cotton Association' in October, 1921, under the Indian Companies Act, 1913. The Government, however, withheld statutory recognition from this Association for a time as it had failed to command the allegiance of all the sections of the trade, particularly that of the brokers and the Mill-Owners' Association. The differences were, however, soon bridged and in 1922 the Government of Bombay enacted the Bombay Cotton Contracts Act, and granted recognition under it to the East India Cotton Association for the purpose of regulating futures trading in cotton in Bombay.

Certain sections of the trade, however, were never reconciled to the idea of a single association controlling the cotton trade, and taking advantage of a loophole in the Act, formed 'The Shree Mahajan Association' in July, 1925, as a rival body. The New Association provided for one hedge contract, viz., 'Fully Good Broach' and the unit of trading adopted was 20 bales as against 100 bales prescribed under the Rules of the East India Cotton Association. There were certain other sections of the trade which also complained against the working of the East India Cotton Association and demanded a review of the situation. In June, 1930, therefore, the Government of Bombay appointed another committee under the chairmanship of Sir Gilbert Wiles to examine *inter alia* the working of the Cotton Contracts Act, 1922, and to make recommendations regarding the better organisation of forward trading in cotton. The principal recommendations of this Committee were that forward trading in cotton should be under the control of a single association and that the growers of cotton should be given representation of the Board of the East India Cotton Association. The Government of Bombay accepted the recommendations, but owing to the strong opposition amongst traders to the idea of a single association, effect could not be given to all the recommendations. At the instance of Bombay Government, two representatives of growers nominated by the Indian Central Cotton Committee were, however, added to the Board of the East India Cotton Association. The Bombay Cotton Contract Act of 1932, which replaced the Bombay Cotton Contract Act of 1922, provided for five representatives of growers on the Board, three nominated by the Indian Central Cotton Committee and two by the Government of Bombay. The Shree Mahajan Association continued to function, however, side by side, with the East India Cotton Association during this period. On the outbreak of the Second World War in 1939, attempts were again made to bring about a merger between the two associations, but these did not succeed.

The inflationery situation created by excessive speculative operations induced by the War-time conditions soon compelled the Central Government to bring the trade under its own control and an Ordinance was issued under the Defence of India Rules imposing a ban on 'options and forward contracts in the new cotton crop' throughout British India. In May, 1943, the ban was made applicable to the current crop of cotton as well, and all the forward business was closed at rates fixed by the Government. After about five months, forward trading was permitted again, but it was allowed only in the 'ring' of the East India Cotton Association (Plate XV) and was made subject to the floor and ceiling rates fixed by the Covernment of India for each season and to the deposit requirements laid down in respect of weekly net 'long' or net 'short' position of each member of the Association.

The market functioned under the War-time Ordinance until 18th January, 1948, when cotton trade was decontrolled. Thereafter, the market operated freely without any restriction until a sharp rise in prices led to the reimposition of control in August, 1948. The market then operated satisfactorily until December, 1949, when the price of the Indian Cotton Contract rose to the ceiling prescribed and trading was suspended. The forward market remained closed for the following three years. In December, 1952, the Government of India again gave permission for the opening of the market in Bombay subject to certain safeguards and the prescribed floors and ceilings.

It was but natural that the city of Bombay, being the largest distributing and exporting centre for cotton, should play such an important part in the development of futures trading in this commodity. This, however, does not mean that there was no tradition of futures trading in other parts of the country. Futures trading was conducted on an appreciable scale at Ahmedabad, Surat, Dhrangadhra and Surendranagar in Bombay, and at Khamgaon, Ujjain, Indore and Ratlam in Madhya Pradesh. At some of these centres, trading was also subject to a measure of Government control.

The Bombay Forward Contracts Act, 1947, and the Forward Contracts (Regulation) Act, 1952. After the end of the Second World War the Bombay Forward Contracts Control Act was passed and all the previous legislations regarding the control of forward markets in the State were consolidated. It was a permissive Act and it was applied to cotton by notification on the 1st April, 1948. It vested certain regulatory powers in the State Government, but did not set up any independent body for continuous supervision. After the political Independence of the country, stock exchanges and futures markets were included in the Union List of Powers under the new constitution and it was decided to undertake central legislation on the subject. The Forward Contracts (Regulation) Act, 1952, was accordingly enacted and brought into force on the 24th August, 1953.

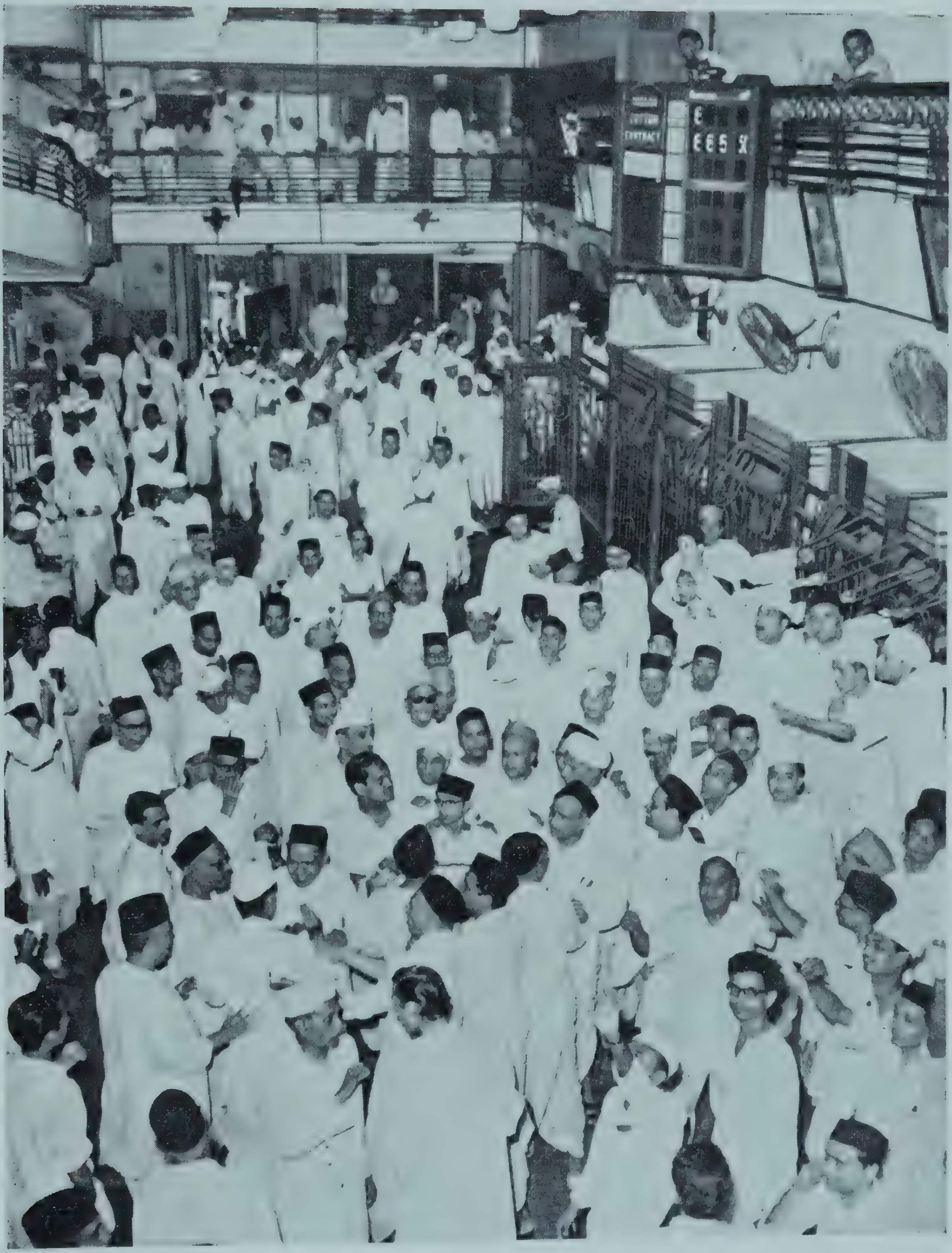
This Act also is an enabling measure and its regulatory provisions are applied by notification to particular commodities and areas. It prohibits options but permits transferable specific delivery contracts and 'hedge' or 'futures' contracts. It also provides for the inclusion of non-transferable specific delivery contracts within its ambit in special cirmumstances. The regulation of trade is effected ordinarily through recognised associations but these associations have to work under the general supervision and direction of a special statutory authority, viz., the Forward Markets Commission.

The Forward Contracts (Regulation) Act was applied to full pressed, half pressed or loose Indian cotton in July, 1954, and the recognition previously accorded by the Government of Bombay to the East Indian Cotton Association

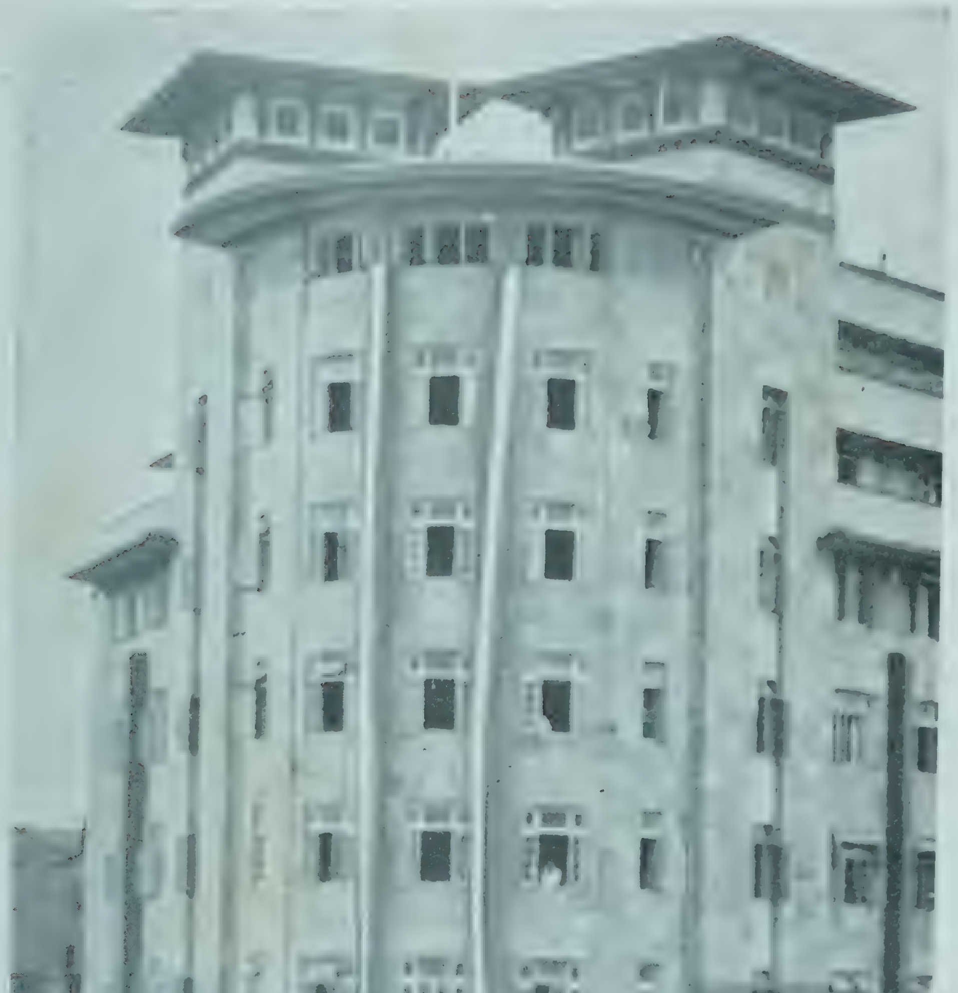
Spot Cotton Market, Sewri (Bombay)

PLATE XIV

Cotton Carts Parked at a Market Yard



East India Cotton Association—Trading Ring



Cotton Exchange Building, Marwari Bazar (Bombay) was continued under the Act and later confirmed on a permanent basis in June, 1955. The Government of India also accorded recognition to the Central Indian Cotton Association, Indore. This new association at Indore is still in its infancy and trading is, therefore, confined at present principally to the East India Cotton Association, Bombay.

Present Working of the East India Cotton Association (E.I.C.A.). The East India Cotton Association has about 750 members representing different interests, such as merchants, exporters, importers, millowners and brokers. The membership is open to any person of good character and adequate credit, on payment of the prescribed admission fee, deposit and annual subscription. The management of the Association is vested in a Board of 15 elected directors, including the President and the Vice-President.

Futures trading is conducted in the 'ring' maintained by the Association in its own building at Kalbadevi (Plate XVI). The trading activities of the members are governed by the detailed rules and regulations of the Association. The principal changes which the Forward Markets Commission introduced in the constitution and the working procedures of the East India Cotton Association when it was recognised under the Forward Contracts (Regulation) Act, 1953, were as follows :

1. It provided for the appointment on the Board of the Association, of a representative of the Central Government and three nominated representatives of interests not directly represented through the membership of the Association.
2. It introduced the system of margins requiring payment of additional deposits by members when their net open position exceeded a specified limit.
3. It provided for the submission of information by the association in regard to the volume of trading of its members on their own account and on account of their clients.

System of Hedge Contracts in Cotton at the E.I.C.A. The question of providing a proper system of hedge contracts which would furnish adequate hedging facilities for the whole of the Indian cotton crop had been a subject of controversy since the formation of the E.I.C.A. The question assumed greater importance in 1943 when this Association alone was permitted to provide hedging facilities in the country.

Prior to the year 1942, the E.I.C.A. permitted five hedge contracts, viz., Fully Good M.G. Bengal, Fine M.G. Oomra, Fully Good M.G. Oomra, Fully Good M.G. Broach and Good M.G. Southern. However, the Fully Good M.G. Oomra ad Good M.G. Southern were more or less inoperative, very few bales being annually tendered under them. In July, 1942, the system was revised in accordance with the recommendations of a special committee and only one hedge contract known as the Indian Cotton Contract, having Fine M.G. Jarila with 3/4 inch staple as the basis, was provided

TABLE 24. VARIETIES OF COTTON TENDERABLE UNDER INDIAN COTTON CONTRACT

	Description of the variety	Maximum staple length up to which tenderable	Places at which tenderable
1.	M. G. Moglai Jarila 25/32″ Staple, including Jarila grown in Bombay State and Goarani (Bani)	27/32″	Ahmednagar, Jalna, Sailu, Aurangabad
2.	M. G. Madhya Bharat Jarila 25/32″ Staple, including Cambodia, Upland and Malvi	27/32″	Ujjain, Indore
3.	M. G. Madhya Pradesh Jarila 25/32″ Staple, including Virnar, (197/3) Verum, M. P. Cambodia, H.420	27/32″	Khandwa, Wardha, Nagpur, Wun, Akola, Amraoti, Karanja, Yeotmal, Khamgaon, Malkapur
4.	M. G. Khandesh Jarila 25/32″ Staple, including Virnar (197/3)	27/32″	Jalgaon, Pachora, Dhulia, Hingoli
5.	M. G. Dholleras 25/32″ Staple, including Cutch, 1027, Kadi, Viramgam, Kadayo, Wagotar, Lalio, Kalagin	27/32″	Morvi, Dhrangadhra, Manavdar, Surendranagar, Anjar
6.	M. G. Kalyan 25/32″ Staple, including certified cotton grown in Rajkot Division of Bombay State	27/32″	Ahmedabad, Viramgam, Kodi
7.	M. G. Rajasthan-American 25/32″ Staple	27/32″	Bijainagar
8.	M. G. Western 25/32″ Staple, including 881F, Umri, Northerns, Hagari I (Western Farm) and Nandyal 14	27/32″	Adoni, Bellary, Raichur
9.	M. G. Vijay 26/32″ Staple, including Digvijay, Nandurbar, Surti and Dehgam, 1027	28/32″	Broach, Dabhoi, Kapadranji, Miyagam
10.	M. G. Ankleshwar 27/32″ Staple, including cotton grown at Ankleshwar, Rajpipla, Jhagadia, Netrang and Nawapur	29/32″	Jagadia, Kosamba
11.	M. G. Surti 28/32″ Staple, including Suyog and Vijalpa (2087)	30/32″	Surat, Navsari, Bardoli
12.	R. G. and S. G. Punjab-American L. S. S. 27/32″ Staple	29/32″	Abohar, Fazilka, Giddarbha, Muktasar, Malout, Sri Ganganagar

13.	R. G. and S. G. Punjab-American 320F, 27/32″ Staple	29/32″	Abohar, Fazilka, Muktasar, Malout, Giddarbha, Tarn Taran, Khanna, Kotkapura, Kaithal, Hansi, Dhuri, Nabha, Rampuraphul, Sri Ganganagar
14.	R. G. and S. G. Punjab-American 216F, 28/32″ Staple, including H.14 (uncertified)	30/32″	Abohar, Fazilka, Muktasar, Malout, Giddarbha, Taran Taran, Khanna, Kotkapura, Kaithal, Hansi, Dhuri, Nabha, Rampuraphul
15.	M. G. Jayadhar (A), 28/32″ Staple	30/32″	Hubli, Gadag
16.	M. G. Jayadhar (B), 27/32″ Staple	29/32″	Bagalkot, Bijapur
17.	M. G. Laxmi (A), 28/32″ Staple, including M. A. 5	30/32″	Gadag, Hubli
18.	M. G. Laxmi (B), 27/32″ Staple	29/32″	Bijapur, Bagalkot
19.	M. G. Gaorani, 27/32″ Staple, including Gaorani 6 and 12	29/32″	Nanded, Hingoli, Latur, Umri, Parbhani
20.	M. G. Buri-American, 27/32″ Staple, including Buri 107, Indore 1, Buri 0394, Udaipur, American and Indore 2	29/32″	Amraoti, Yeotmal, Khandwa
21.	M. G. Parbhani-American 27/32″ Staple	29/32″	Adilabad
22.	M. G. Cambodia, 29/32″ Staple, including Avanashi, Cambodia Co.2, Cambodia Co.4 including Co. 4/B.40 and Madras Cambodia Uganda (M.C.U.) 1 and 2, otherwise known as Rajapalayam and also Cambodia Co.2, Co.4, 170-Co.2 and 134-Co.2-M grown in Bombay State	31/32″	Tirupur, Coimbatore, Virudhunagar
23.	M. G. Karunganni, 28/32″ Staple, including Tinnevelly, Salems (Nadam, Bourbon and Uppam) Karunganni 2 and Karunganni 5	30/32″	Tuticorin, Coimbatore

The principal factors responsible for bringing about this change were: (*i*) alteration in the character of Indian cotton due to varieties with a staple length of 3/4 inch and over gaining preponderance in production; and (*ii*) the need for a hedge contract having as its basis a cotton which catered to Indian domestic economy rather than short and fair staple cotton. The demand for short staple cotton had sharply fallen owing to the loss of overseas markets due to the exigencies of the War and the fair staple Broach cotton had lost its representative character as a result of the crop improvement work done in the country. Under the new contract, nearly three million bales of different varieties of Indian cotton were made tenderable provided they had a minimum of 3/4 inch staple. Staple length was recognised in the future contract for the first time. From July, 1942, to June, 1956, there was only one hedge contract known as the 'Indian Cotton Contract' at the E.I.C.A., although the basis of the contract was altered twice to suit changing conditions in the supply position and improvement in the quality of cotton. In June, 1956, the single contract was replaced by two hedge contracts, viz., the Fine Jarila Contract and the Fine Vijay Contract. This system of two contracts lasted only for about a year and in June, 1957, the Association again reverted to a single contract in view of the shortage of the crop. Thus, at present, there is only one hedge contract styled 'The Indian Cotton Contract.'

The basis of the Indian Cotton Contract is Fine M.G. Moglai Jarila, staple 25/32 inch, as per standard prepared from Jarila cotton grown in the former State of Hyderabad. The varieties of cotton with their respective basic staple lengths tenderable under the Contract are shown in Table 25.

The Standard samples prepared for each of the varieties tenderable are: (*i*) Extra Superfine; (*ii*) Superfine; (*iii*) Fine (Basis); (*iv*) Fully Good; (*v*) Good to Fully Good; and (*vi*) Good. Cotton below the standard 'Good to Fully Good' is rejected. The standards laid down for staple are 24/32, 25/32, 26/32, 27/32, 28/32, 29/32, 30/32 and 31/32 inch.

The Terms of Contract at the E.I.C.A. The Association at present provides for three deliveries during each cotton year ending 31st August, viz., March, May and August. The tenders against each delivery are permitted on specified days between the 1st and the 25th day of the delivery month. The tendering differences, i.e., the premia or discount, for the delivery of cotton other than the basis variety, are fixed for each delivery separately on the basis of the difference between the spot price of basis cotton and the spot rate of the variety concerned, in the Bombay and interior markets. These differentials are fixed five days before the commencement of the delivery period, by a special committee consisting of seven persons actively connected with the spot market and representative of all panels of members. The contract is basically for delivery at Bombay but delivery at some sixty other centres is also permitted subject to the condition that the seller should bear the cost of transport from the delivery centres to Bombay. The Unit of trading is 50 bales of 392 lb. each and the unit for the purpose of quotation of price is a candy of two bales.

The crux of the problem of hedging in cotton is the movement of the spread between the price of the futures contract in cotton and the price of the cotton in the spot market. The weather, the market situation, the supply and demand position, the policy of Government in respect of exports and imports and the extent of speculation are the main factors which affect the spread between ready and futures prices. Figure 22 shows the monthly average Futures and spot prices of cotton in Bombay.

Buying or Selling Cotton 'On Call'. Textile mills buying futures as a hedge against forward sales of cotton goods find it difficult to estimate correctly the price changes in respect of finished goods. Hence, they resort to the system of buying or selling 'on call'. Under this system, the mill makes a contract with a dealer to deliver to it at a future date to be chosen by the mill, the required cotton at a price which was a fixed number of points 'on' (i.e., above) the price of the futures ruling on that date. In other words, it fixes the 'spread' at certain points above the price of the futures, but does not settle the actual price till it considers that the time is opportune to call cotton from the dealer. The cotton is generally called by the mill when it is in a position to sell the manufactured goods or when the price situation in respect of those goods is clearer to it. However, the mill is required to call the cotton before the particular futures contract with reference to which the agreement was made, expires. The principal advantages of the call system are that, firstly, it enables the mills to choose the price of raw cotton in line with the sale value of the manufactured product and, secondly, it ensures that cotton of the particular grade would be available in adequate quantity. The volume of 'Call Contracts' outstanding is an indication of the potential demand for cotton.

TREND OF PRICES

As in the case with all other commodities, the primary price determinants for cotton are the basic forces of supply and demand. Some of the main factors that influence supply of the cotton are the acreage planted, seasonal rains, plant diseases and pests, floods and the level of raw cotton prices and the cost of production. Some of the factors which influence demand are export-import operations, buying policies of mills and the consumer demand for different styles of cloth.

Ready and Futures Prices. The existence of a futures market leads to the prevalence of two price quotations, the spot price and the futures price. These prices depend, at any time primarily on the supply and demand situation and the eagerness of the market to buy and sell cotton in ready and

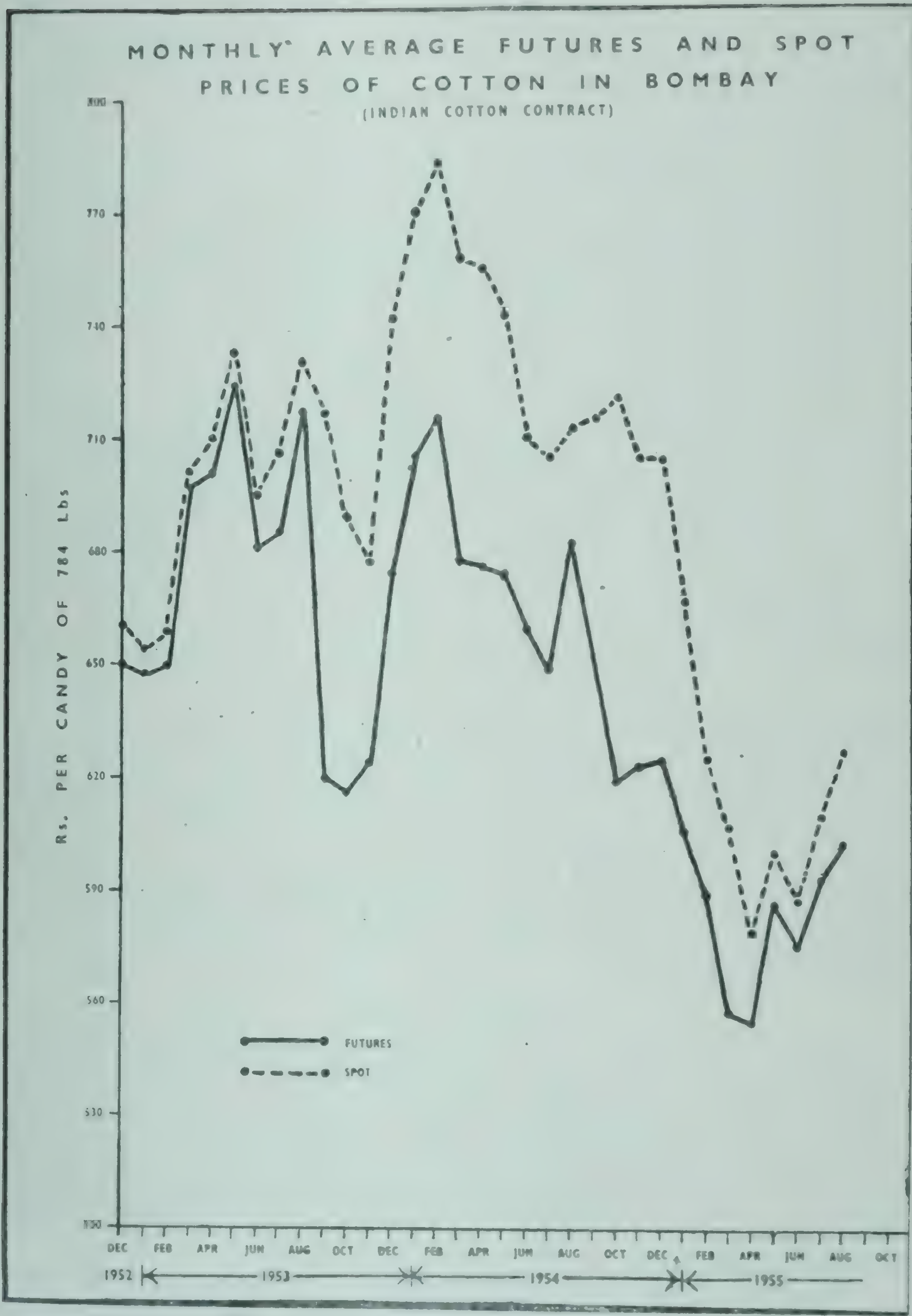


Fig. 22. Futures and Spot Prices

futures contracts, respectively. The futures price is generally more sensitive than the ready price. It reacts quickly to such factors as the condition of the crop in the producing countries, the acreage planted, the amount carried over from the previous year, the visible supply, the probable quantity still in the hands of the growers, the quantity likely to be exported, the demand for importing countries and the rate at which the domestic mills make their purchases. The evaluation of the prospects may change materially from hour to hour and from minute to minute and so also the futures price.

Relation Between Ready and Futures Prices. Normally, the futures price remains above the ready price so as to cover the cost of carrying the stocks to a future date. These costs are made up of the cost of storage and insurance, the interest on the investment in stocks, and the value of stocks lost due to deterioration, wastage and adverse price changes during the currency of the contract. The sensitivity of the futures market to slight changes in demand and supply and the general practice of the sellers to concentrate deliveries on the varieties which are in relatively large supply, however, often impair the normal relationship between the two prices. But the futures contract calls for the supply of the actual commodity in the delivery month. This tends to maintain the normal price relationship Though actual delivery rarely takes place, the right to take or give delivery acts as a check on any abnormal divergence of ready futures prices. Moreover, if the futures price for the contract quality remains substantially out of parity with the ready price for any length of time, arbitrage transactions take place and correct the situation.

There is a constant tendency for the spread between the ready and futures prices to narrow during the life of any contract. There are two reasons for this : (*i*) the cost of carrying the commodity to the maturity date of the contract declines steadily; and (*ii*) the contract has to be settled during the month of maturity either by taking or by making delivery of the commodity, or by exchanging the difference.

Futures and Ready Prices During and After the War. Since 1943, cotton prices in India have been subject to floors and ceilings prescribed by the Government of India and to the 'on' and 'off' allowances fixed officially for the different standard grades. A study of the relationship between the futures prices and the ready prices of cotton reveals that in the period prior to 1939 and during the years 1946-47 and 1947-48, the relationship conformed more or less to the pattern indicated above. In 1948-49 and 1949-50, trading was suspended frequently because cotton prices approached or touched the prescribed ceilings. In the years 1950-51 and 1951-52, the futures trading remained prohibited. Since the season 1952-53, there has been a reversal of price relation or a 'backwardation', i.e., the futures price has been lower than the ready price for the basis variety. The average monthly quotations for the three deliveries, viz., February, May and August, of the Indian

Cotton Contract together with corresponding 'ready' prices of M.G. Jarila (Basis) for the three seasons 1952-53, 1953-54 and 1954-55 are given in Table 25. It will be observed that 'spot' prices during this period invariably remained higher than the 'futures' quotations, the difference being most marked from August, 1953, to March, 1955.

The principal reasons responsible for this inverted relationship were as follows :

1. The Indian Cotton Contract that was then traded at the E.I.C.A. was a very wide contract. Too many different varieties of cotton were tenderable against it. The great uncertainty of the variety which a buyer might receive in fulfilment of the contracts had a depressing influence on futures price.
2. The tendering differences of the tenderable varieties were fixed with reference to the price of the hedge contract instead of the differences prevailing between the spot prices of the varieties concerned. This insulated the contract to a great extent from the conditions prevailing in the ready market and made its price dependent upon the expectations of traders as to what the price of the contract would be at the time of fixing the tendering differences.

Prices at Mofussil Centres. The fluctuations in the futures price of one representative variety usually reflect the changing conditions in the entire crop which it represents. To the traders who operate in the ready markets in the interior and are unable to assess all the relevant factors affecting supply and demand, the futures price provides a reliable guide in their transactions. The cotton transactions between merchants at the important mofussil centres, particularly in those having traditions of futures trading, take place principally on the basis of the futures price ruling at the E.I.C.A. Bombay.

Central and Mofussil Prices. The monthly averages of daily ready prices of cotton for the season 1955-56, calculated to a common unit at Bombay and certain important mofussil centres, are given in Table 26.

It will be noted from the table that, on the whole, the prices at these markets moved in sympathy with one another and that the prices at Bombay were generally higher than the prices at the mofussil centres for the same variety. The difference between the prices at Bombay and at the mofussil centres decreased with the advance of the season.

Internal and External Prices. Prior to the Second World War, the prices of cotton at important world centres like Bombay, New York and Liverpool were generally in line with each other. This was largely due to the arbitrage business that was carried on between these important centres. Any disturbance in the 'normal parity' between the prices at different markets would stimulate the arbitrageurs to buy futures in a relatively cheaper market and simultaneously sell futures in a relatively

TABLE 25. MONTHLY AVERAGE FUTURES AND SPOT PRICES AT THE EAST INDIA COTTON ASSOCIATION FOR THREE SEASONS (1952-53 TO 1954-55)

Year	Month	Futures price			Spot price
		February	May	August	M. G. Jarila (basis)
		1953	**1953**		
1952	September	No trading from the 1st September to the 11th December			
	October				
	November				
	December	650	659	—	660
1953	January	647	659	—	654
				1953	
	February	649	658	675	658
	March	—	697	709	702
	April	—	702	712	710
	May	—	724	734	733
	June	—	—	681	695
		1954			
	July	667	—	688	706
	August	656	—	718	729
			1954		
1953	September	619	621	—	715
	October	612	616	—	690
	November	628	634	—	678
	December	672	671	—	741
1954	January	703	697	—	770
	February	717	698	—	783
				1954	
	March	—	676	687	757
	April	—	674	691	754
	May	—	692	688	742
	June	—	—	660	710
	July	—	—	649	703
	August	—	—	683	713
1954	September	—	—	—	715
		1955			
	October	618	—	—	721
	November	626	—	—	706
	December	628	620	—	706
1955	January	606	598	—	667
	February	588	574	—	625
				1955	
	March	—	558	565	606
	April	—	552	562	577
	May	—	585	576	600
	June	—	—	576	588
		1956			
	July	614	—	593	609
	August	628	—	612	628

dearer market. The main factors which entered into the calculation of 'normal parity' were the rates of exchange, shipping charges, tariff duties, etc. The arbitrage business between India and Liverpool was particularly popular in India because of the stability of the exchange rate between India and the United Kingdom.

TABLE 26. MONTHLY AVERAGES OF DAILY READY PRICES OF COTTON AT CERTAIN IMPORTANT CENTRES (1955-56)*

Centres	Bombay	Abohar	Khamgaon	Amraoti	Ujjain	Indore
Months	M. G. Jarila 26/32″	320F	197/3 13/16″ fully good	Jarila 25/32″		
September	650	Not available				
October	—					
November	776					
December	783	771	745	681	680	676
January	766	794	732	705	682	707
February	767	792	740	727	672	687
March	765	771	746	730	695	708
April	774	816	758	730	728	730
May	801	827	813	750	741	777
June	820	—	812	—	780	774
July	819	—	817	—	772	749
August	830	—	817	—	791	768

* Rs. per candy of 784 lb.

Since the Second World War, there has been a persistent disparity between the prices at the important international markets. This has been mainly due to internal price control, regulation of exports and imports and control of foreign exchange transactions by the various Governments. In India, all the three types of controls are in operation at present and no arbitrage business with external markets is permitted.

PROBLEMS OF MARKETING

Reduction of Marketing Costs. The modern methods of marketing while giving many facilities, to both the producer and the consumer, have on the one hand, increased the cost of cotton to the consumer and, on the other, reduced the share of the grower in what the consumer pay for the commodity. It is natural that the consumers of raw cotton should expect the marketing system to provide adequate supplies of cotton of appropriate qualities at the lowest possible cost, and the farmers should expect it to give them the largest possible return for their produce. Therefore, the central problem of marketing is how to carry out with maximum efficiency and minimum cost the various marketing functions, viz., assembling, processing, transport, storage and distribution.

TABLE 27. COST OF MARKETING OF LINT (candy of 784 lb.)

	Bombay		Madras		Mysore		Punjab		Indore (ex Mills)		Average	
	(Surat to Bombay)		(Tiruppur to Coimbatore)		(Hubli to Bombay)		(Tarn Taran to Bombay)					
	Cost (Rs.)	Per cent.	Cost (Rs.)	Per cent.	Cost (Rs.)	Per cent.	Cost (Rs.)	Per cent.	Cost (Rs.)	Per cent.	Cost (Rs.)	Per cent.
Transport from farm to *mandi*	8·61	8·5	11·75	15·1	11·62	7·5	—	—	4·00	5·4	7·70	6·7
Assembling at the wholesale market	6·03	5·9	24·06	31·0	21·96	14·3	20·48	16·0	7·81	10·4	16·07	15·0
Processing:												
Ginning	33·62	33·1	30·00	38·7	64·0	41·6	34·00	26·5	48·19	64·5	41·96	39·1
Loss in ginning	8·86	8·7	—	—	—	—	26·87*	—	9·11	12·2	3·60	3·3
Transport cost from *mandi to* destination	8·69	8·6	5·25	6·8	22·84	14·8	14·54	11·3	—	—	10·27	9·6
Distribution costs:	7·08	7·0	5·00	6·5	18·78	12·2	25·27	19·7	1·75	2·3	11·58	10·8
Loss in handling	12·75	12·5	—	—	—	—	—	20·9	—	—	7·93	7·4
Miscellaneous:												
Insurance, interest, etc.	15·95	15·7	1·50	1·9	14·74	9·6	7·23	5·6	3·89	5·2	8·60	8·1
Total marketing costs	101·59	100·0	77·56	100·0	153·94	100·0	128·39	100·00	74·75	100·00	107·71	100·0

* Separate figures not available; includes loss in handling.

An *ad hoc* study of the marketing costs incurred during the movement of *kapas* from the farm to the textile mills was recently made by the Directorate of Marketing and Inspection at five centres, namely, Surat (Bombay), Hubli (Mysore), Tirupur (Madras), Tarn Taran (Punjab) and Indore (Madhya Pradesh). The costs of the important marketing processes are indicated in Table 27. It will be observed therefrom that about 39 per cent. of the average overall cost is made up of the ginning and pressing charges and nearly 26 per cent., of the merchandising charges at the assembling and distributing centres. The percentage spread of prices from the producing areas to the consuming centres is shown in Table 28.

TABLE 28. PERCENTAGE PRICE SPREADS FOR COTTON IN DIFFERENT STATES

	Madhya Pradesh	Madras	Mysore	Bombay	Punjab
Producer's share	90·11	88·00	82·05	91·54	86·07
Merchandising charges (at assembling and distributing centres)	1·04	2·92	4·06	1·04	4·18
Processing cost	5·11	3·01	6·38	2·68	3·11
Merchant's profit	1·95	3·98	2·60	0·40	2·19
Transport	0·42	1·71	3·44	1·37	1·33
Others	0·96	0·38	1·47	2·97	3·12

In Surat tract of Bombay State, the Vijalpa variety of cotton is usually sold as lint to the merchants or processing factories through co-operatives. In other tracts, viz., the Punjab, Mysore, Madhya Pradesh and Madras cotton is generally sold by the farmer as seed-cotton in the wholesale markets or in villages. As a result of this difference in the methods of assembling and distributing, the marketing charges also are different. In view of this, the price spreads given above are not strictly comparable. Nevertheless, the information collected emphasises the need of reducing the expenditure on certain items, such as processing and merchandising, which collectively account for over 64 per cent. of the total cost of marketing.

The charges for both ginning and pressing are rather high. The loss of weight during the ginning process is additional. The loss in ginning could be reduced if the cultivators picked the *kapas* in a clean state. The cost of ginning, on the other hand, can be reduced only if the working of the factories is made more efficient. All surplus factories in an area should be suitably dispersed so as to provide a whole season's work for the remainder and thus reduce their overhead costs. The maintenance and repair of the old machinery should also be properly attended to.

As regards the merchandising charges, these can be lessened if the number of intermediaries is reduced by eliminating unessential agencies or entrusting some of these functions to farmers' co-operatives. The organisation of co-operative sale societies and working of co-operative ginning and pressing factories are suggested to increase the cotton grower's share in the price paid by the consumer mills.

Measures for Improvement. There is no other commodity in India whose marketing can be said to be better organised than that of cotton. While this is true of the terminal market at Bombay which has a cotton exchange and where the trading technique is developed to suit the export market, it is not true of the interior markets. In the up-country, barring a few regulated markets, the marketing conditions still continue to be chaotic and disorganised with the result that the producer is seldom able to realise his due share of the consumer's rupee. With the expansion of the Indian textile industry, the pattern of cotton economy has considerably changed.

The vast bulk of the cotton produced in the country is now retained for home consumption. The system of centralised marketing which was evolved for an export economy does not suit the changed conditions, and causes duplication and waste in the present context. There is, therefore, imperative need for reorientating the cotton marketing system, particularly in the interior markets, in the interests of primary producers.

To facilitate an orderly marketing of cotton suggestions have been made from time to time for : (*i*) regulation of markets; (*ii*) promotion of co-operative marketing and processing ; and (*iii*) provision of warehousing facilities. Though the regulation of wholesale cotton markets during the past 25 years has standardised the market practices and market charges, the exploitation of the illiterate and ignorant small producer continues almost unabated. The weighment of cotton in 90 per cent. of the markets is done at the ginning factories. This leads to disputes between buyers and sellers, resulting ultimately in the reduction of prices actually paid to the producers. In some of the markets, secret bidding of prices and the *fardi* system of fixing the selling rate for the day are still in vogue, to the detriment of the farmer. Prof. Dantwalla while reviewing the working of the Bombay Agricultural Produce Markets Act in that State, recommended *inter alia* that consolidation of the ground already covered should be given priority.

In the local markets, seed cotton of lower grades is recognised and purchased at low rates but not separately ginned and pressed. On the other hand, the cotton of higher grades is bought on a flat basis, i.e., on the day's rate. Thus higher grades and cleaner picked cottons are not recognised and receive no premium. Similarly, staple differences between lots of the same trade variety are not recognised and rewarded. All efforts to improve quality will fail if the local markets are slow to recognise and adequately reward a quality product. Mixing of different qualities by ginners and merchants in up-country markets is another problem demanding the most serious attention of all concerned. Such fraudulent mixing is ruining the fair name of improved varieties and causing serious financial losses to their growers.

The cotton co-operatives have not made much progress in the States other than Bombay. The system of licensed warehouses, which would provide cheap finance to the cotton producers against hypothecated goods, is yet to be introduced in the country.

The Committee of Direction of the Reserve Bank of India in their report on the Rural Credit Survey had suggested an integrated scheme for the marketing of agricultural commodities on co-operative lines. As recommended by this Committee, a programme for promoting co-operative marketing and for establishing warehouses for agricultural commodities has been drawn up by the National Co-operative Development Board, constituted by the Government of India under the Agricultural Produce (Co-operation and Warehousing) Development Act, 1956. The programme includes the setting up of 1,800 co-operative marketing societies in the country by strengthening the existing societies and/or by organising new ones. It also envisages the establishment of 48 co-operative cotton ginning and pressing societies during the Second Five-Year Plan period. The programme for establishing licensed warehouses provides for the setting up of 100 national warehouses by the Central Warehousing Corporation and 250 warehouses by the State Warehousing Corporation.

The above programme of marketing improvements can be implemented only through positive action by the State and Central Governments and by individuals as well as farmers' organisations. While the Governments may enact necessary laws, such as the Agricultural Produce Markets Act and Forward Contract (Regulation) Act, for the regulation and control of the marketing system, and provide funds for establishment of warehouses and co-operative organisations, the producer-sellers must play their role in making them work successfully. The grower who, at present, is not alive to his marketing problems must shake off his indifference and take interests in the marketing of his farm produce. A marketing sense has to be created in him and he is to be educated in regard to improved methods of marketing, the benefits of selling in the regulated markets and of co-operative marketing and warehousing. This will strengthen his bargaining position. Owing to his ignorance, he is at present unable to figure out the parity price of cotton on the basis of the spot or futures' prices ruling in the Bombay market. The prices and other market information, therefore, should be made available to him in an easily intelligible form. To achieve all this, a concerted and sustained effort is necessary. The State Marketing Departments should take up early steps to organise extension work in the cotton producing areas with a view to preparing producers for the improvements contemplated in the marketing system of cotton.

CHAPTER IV

CONSUMPTION OF COTTON SEED

INTRODUCTION

This chapter deals with the production and marketing (consumption) of cotton seed and its products, viz., oil, meal (cake), linters and hulls.

Cotton, as harvested and brought to the gin, consists chiefly of two products, cotton lint and cotton seed. The ginning process separates the lint from the seed. The proportion of lint to seed in any given quantity of seed-cotton (*kapas*) varies, depending primarily on the variety and also on the locality, season, soil and climatic conditions. Thus, the proportion of lint to seed from the same variety varies with the locality and the season. The quantity of lint obtained in the gins from 100 lb. of seed-cotton is termed as the ginning factor or ginning per cent. The variation in the ginning per cent. is greater in the *desi* cotton varieties than in the American. For instance, it varies from 22 per cent. in Northerns in Andhra Pradesh, and in Nadam and Uppam in Madras State, to 44 per cent. in Comillas in Assam and Tripura States, where as it varies only from 30 per cent. in Parbhani-American in Hyderabad State to 38.4 per cent. in 170-Co.2. While the variation in the ginning per cent. in the United States is also governed by the above factors, the range of variation of 16 varieties at 16 locations in 1935 and 1936 varied from 31.5 per cent. to 38.8 per cent. giving an average of 35.5 per cent. (Bailey, 1948a). In estimating cotton seed production in India, a uniform average ginning percentage of 33-1/3 is being used. In view of the considerable variation in the ginning per cent. of the different varieties of Indian cotton, it appears that by taking the lint/seed ratio conforming approximately to the actually realised yields (Bailey, 1948b) for each variety in each State in each year, a more accurate estimate of the production of cotton seed may be arrived at. Even in the United States, where an average lint/seed ratio of 35 was used till 1943, the Census Bureau modified its lint/seed ratio to conform approximately to actually realised yields from the 1943-44 season. The fuzz left over on the seed coming out of the gins is called the linters and this term is used throughout this chapter.

PRODUCTION OF COTTON SEED

India was the third largest country in the world in the production of cotton seed in 1954-55—it was the fourth during previous years—and accounted for about one-tenth of the total world production. The acreage under cotton is nearly one-fourth of the total world acreage. The production of cotton seed in the principal cotton producing countries of the world for the years 1952-53 to 1954-55 is given in Table 29.

TABLE 29. PRODUCTION OF COTTON SEED IN PRINCIPAL COTTON PRODUCING COUNTRIES OF THE WORLD FOR THE YEARS 1954-55 TO 1956-57

Country	1954-55	1955-56 (thousand tons)	1956-57
Argentina	218	254	216
Brazil	778	765	720
China*	(1,430)	(1,620)	(1,540)
Egypt	662	638	622
India	1,479	1,399	1,653
Mexico	650	857	618
Pakistan	562	608	597
Peru	181	171	177
Soviet Union*	(2,136)	(1,975)	(2,230)
Sudan	170	186	230
Syria	139	147	160
Turkey	256	280	289
Uganda	110	131	125
U.S.A.	5,097	5,396	4,828
Others	1,200	1,134	1,161
Total	15,068	15,561	15,166

* Official statistics not available.

Cotton produced in India belongs mainly to the species of *Gossypium arboreum*, *G. herbaceum* and *G. hirsutum*. The *desi* varieties of cotton come under the first two species and the American varieties under the third. About 50 varieties of *desi* and American cottons are at present produced on a commercial scale in India. The production figures of the more important *desi* and American variety seeds are given in Table 30. These are estimated from the production of lint and the ginning per cent. of each variety in each State for each year.

The production of the American type seed is increasing year after year. It rose steadily from 11.9 per cent. of the total seed production in 1950-51 to 25.7 per cent. in 1955-56.

The production of cotton seed in India is usually estimated from the estimates of lint produced, using an average proportion of seed to lint at 2 : 1. The estimated production of cotton seed in the various States in India made on this basis is given in Table 31.

The estimated production of cotton seed in the re-organised States for the years 1956-58 is given in Table 32.

The revised target for production of cotton fixed for achievement by the end of the Second Plan (1960-61) is 65 lakh bales of lint of 392 pounds each. This corresponds to a production of 22.8 lakh tons of seed on the basis of seed/lint ratio of 2:1.

TABLE 30. PRODUCTION OF IMPORTANT DESI AND AMERICAN VARIETY COTTON SEEDS IN INDIA

Variety	State	Production of seed*		
		1955-56	1956-57 (thousand tons)	1957-58
Desi				
Jarila (including Virnar & 197-3)	Bombay, Hyderabad, Madhya Pradesh	119	206	186
Oomras	Hyderabad, Madhya Pradesh	81	111	114
Vijay	Bombay	117	91	94
Malvi	Madhya Pradesh, Rajasthan	136	91	85
Goarani	Hyderabad	35	100	84
Suyog (including 2087)	Bombay	65	57	49
Jayadhar	Bombay, Hyderabad, Mysore	77	44	51
Kalyan	Bombay, Saurashtra	53	29	31
Dholleras	Bombay, Saurashtra	63	79	101
Rajasthan Desi	Rajasthan	27	35	50
Punjab Desi	Punjab, Pepsu	33	56	86
Karunganni	Madras	43	53	51
Westerns	Andhra, Mysore	41	15	15
H. 420 (including Verum)	Madhya Pradesh	29	56	52
American				
320F, 216F, L. S. S.	Punjab, Pepsu, Rajasthan, Uttar Pradesh	169	231	190
Cambodia	Madhya Pradesh, Madras, Saurashtra	60	133	90
Laxmi	Andhra†, Bombay, Hyderabad, Mysore	55	54	40
Buri	Madhya Pradesh	37	39	29
Parbhani-American	Hyderabad	4	5	4

*Estimated from the production of lint and the ginning per cent. of each variety in each State for each year.

†Production figure not included as it is not available.

TABLE 31. COTTON SEED PRODUCTION IN DIFFERENT STATES OF INDIA

State	1953-54	1954-55 (thousand tons)	1955-56
Andhra Pradesh	34	31	37
Bombay	382	444	449
Hyderabad	141	133	115
Madhya Bharat	114	116	125
Madhya Pradesh	237	232	158
Madras	93	95	105
Mysore	43	49	28
Pepsu	64	80	47
Punjab	130	154	164
Rajasthan	40	42	51
Saurashtra	71	88	87
Uttar Pradesh	15	15	9
Assam, Ajmer, Bhopal, Travancore-Cochin, Kutch, Tripura, Orissa and Bihar	25	27	18
Total	1,388	1,504	1,399

TABLE 32. COTTON SEED PRODUCTION IN THE RE-ORGANISED STATES IN INDIA FOR THE YEARS 1956-57 AND 1957-58

State	1956-57*	1957-58**
	(thousand tons)	
Andhra Pradesh	47	44
Assam	3	3
Bihar	Below 500 tons	Below 500 tons
Bombay	762	609
Kerala	3	3
Madhya Pradesh	199	162
Madras	126	137
Mysore	158	179
Orissa	1	1
Punjab	280	289
Rajasthan	59	75
Uttar Pradesh	16	21
Tripura	3	3
West Bengal, Delhi and Himachal Pradesh	Each below 500 tons	Each below 500 tons
Total	1,657	1,664

* Figures worked out from all-India estimates of cotton partially revised estimate 1956-57, using the common ginning per cent. of 33 1/3.

** Figures worked out from the all-India final estimates of cotton 1957-58, using the common ginning per cent. of 33 1/3.

The estimated production, given above, is based on the estimates framed by the State Revenue and Agricultural Departments in the form of crop forecast returns. The estimates so obtained appear to be invariably short of the actuals by a fair margin. For, according to the report of the Indian Delegation to the Eighth Session of the International Cotton Advisory Committee, 1950, "the final forecasts deviate from the actuals by only about one per cent. in the United States (negative and positive) and about five per cent. in Egypt, while in the Indian Union, the estimates were short of the actuals by 11 to 20 per cent., the average being 16 per cent.*

MARKETING AND UTILIZATION OF COTTON SEED IN INDIA

MARKETING

Seed-cotton (*kapas*) is harvested in India by hand-picking only. The harvesting (picking) season varies from State to State, as it is different for different varieties. A number of pickings are made at regular intervals as the bolls mature. There are, however, two main harvesting seasons, one from February to April and the other from September to December. The marketing of cotton commences from within a month of the harvesting and continues for three to four months. The seed cotton is ginned for lint mostly in factories using either power driven roller gins or saw-gins. The seed arrives in the market for sale mainly from 15 days to three months and sometimes even up to six months. The main season for marketing the seed is from March to June in most of the States.

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* **Madras State Marketing Officer, 1950.**

At the gins, *kapas* sold by different farmers is mixed and ginned. Therefore, the seed coming into the market will not be of any single variety but a mixture of two or occasionally more varieties. The main variety normally contains a mixture of the second variety up to 25 per cent. There will be heavy movement of the seed into the marketing channels for three to four months, after a couple of months following the harvesting. But the sale of seed continues for some months even afterwards. The sale of seed mainly takes place at the gins and the market yards. The mills, therefore, purchase and stock as much of the seed as possible. The transport of the seed to the mills or for cattle feed is chiefly by country carts and open or closed lorries, in gunny (jute) bags, from nearby places, and by rail in closed wagons, in gunny bags, from distant places. The seed is not transported in a loose condition. The seed is weighed at the mills in bags, without using any automatic weight-recording machines, as is done in the United States.

As in the case of most other agricultural products in India, no standards are fixed for the sale of cotton seed either for feeding or for milling purposes, nor is any proper grading of the seed done by the millers to evaluate it before buying or processing. The purchase of the seed depends on its type (*desi* or American) and physical condition, judged visually, for feeding, and on its oil content and physical condition, for milling purposes. This results in inequities both to the farmer (seller) and to the miller (buyer). On the other hand, in the United States, where the seed is solely used for processing, after reserving for planting, all mills grade the cotton seed received by them for evaluation, before storage and milling, by determining the extent of the factors in the seed which might effect the quantity and quality of its products. These factors are percentage of oil, ammonia, moisture, foreign matter, linters and free fatty acids. This subject is dealt with in detail later.

HOW COTTON SEED IS UTILIZED AT PRESENT

Cotton seed is an important article of food in India for milch cows, buffaloes and working animals. Till recently, i.e., before the commencement of the milling of cotton seed for oil, all the cotton seed produced in India was being utilised as cattle feed, after meeting the requirements for planting, for which about five per cent. of the seed is utilised. The less fuzzy seed of *desi* varieties is preferred by the farmer for feeding his cattle. But when this is not available in sufficient quantities, even the more fuzzy American type seed is used for feeding the animal. There is considerable inter-State trade in cotton seed for this purpose, usually from surplus States to deficit ones. The prices of the American varieties are, therefore, usually, lower than those of *desi* seeds.

However, during the last few years cotton seed is increasingly crushed for oil. During 1954-55, it is estimated that 56,687 tons of seed was crushed in mills,* corresponding to four per cent. of the seed produced. According to the information furnished by the Ministry of Commerce and Industry, Government of India, in 1956, hardly six per cent. of the seed produced annually is crushed at present. Thus, still about 90 per cent. of the seed is being utilised as cattle feed, resulting in the loss of huge quantities of much valued oil needed for human consumption and large quantities of linters required for industries.

STRUCTURE, COMPOSITION AND CHARACTERISTICS OF COTTON SEED

STRUCTURE

Commercial cotton seed is produced after ginning seed-cotton (*kapas*) for the staple fibre. Cotton seed has three principal parts, viz., linters, hulls and kernel (meat). The quantity of the linters left on cotton seed varies according to the variety of cotton seed. The North American Upland type of cotton seed, *Gossypium hirsutum,* which is the type most commonly grown in the United States, is densely covered with short cotton fibres or linters even after ginning the seed, and ordinarily have, on an average, about 14 per cent. linters. The Egyptian or Sea Island cotton seeds (*Gossypium barbadense*) have no adhering linters (and are properly described as black in colour), as practically all the fibres are removed from them in the ginning operation. The *desi* varieties of Indian cotton seed (*Gossypium arboreum* and *Gossypium herbaceum*) have less linters (in a few varieties as low as one per cent.) than the American type Indian seed. The linters consist mainly of cellulose. The minor constituents are pectins, mineral constituents, nitrogenous constituents, waxes, resins, pigments, water soluble carbohydrates and other substances.

The seed coat (more commonly known as hull) is usually black in colour. However, it may vary from brownish-red to jet-black. The weight of the hulls varies between 40 and 50 per cent. of the weight of the whole cotton seed and varies in thickness from 0.28 to 0.35 millimetre. Even the hull of a single seed is not uniform in thickness. The main constituents of the hulls are cellulose complexes, lignin and furfural, and the minor constituents are tannins, mineral matter, colouring matter and other substances. In between the inner surface of the hull (spermoderm) and the kernel (embryo), there is a thick skin or membrane which forms the attachment to the cotton seed hull at the chalazal cap.

The embryo of the cotton seed, comprising of two cotyledons, the axial organs and the enveloping membrane, contains largely the oil and the protein, besides the pigment glands. The latter contain pigment materials which impart the characteristic yellow-red colour to the cotton seed meal and oil.

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* Oilseeds Crushing Industry Enquiry Committee Report, 1956.

Among the pigments is gossypol. The pigment glands are readily ruptured in the presence of water, where upon their contents flow out and discolour the cotyledon tissue (cotyledons are the principal oil and protein yielding elements of the embryo). The gossypol, however, does not go into water solution, but is oil soluble. The tissue of the kernel also contains starch and calcium oxalate. The oil actually occurs within the cells as an emulsion which upon treatment with water breaks and oil droplets coalesce and appear within the cell as 'free oil'.

COMPOSITION

The major constituents of cotton seed are fat, protein, moisture, crude fibre and carbohydrates. The minor constituents are pigments, phosphorous compounds, sterols, anti-oxidants, mineral compounds and other substances. All these reside entirely or mostly in the kernel. The composition of cotton seed varies within certain limits, with the variety, maturity, conditions of cultivation and environment of the plant, although no definite co-relationship between these factors with regard to any individual component, such as fat or protein is found to exist. Generally, long fibre seeds contain higher amounts of lipids.

Proximate composition of some varieties of cotton seed are given in Table 33. For comparison, the average proximate composition of the United States cotton seed is also included in the Table. Although the proximate composition of the six samples of Indian cotton seed and the average proximate composition of the North American seed appear to be similar, there are striking differences in the composition of the seed of the two countries, as will be seen later.

TABLE 33. PROXIMATE COMPOSITION OF SOME VARIETIES OF INDIAN COTTON SEED

Variety	Moisture per cent.	Oil per cent.	Protein (N × 6·25) per cent.	Crude fibre per cent.	Ash per cent.	Carbohydrates (by difference) per cent.
Cambodia (Madras)	8·83	15·98	18·98	26·10	4·44	25·17
Karunganni (Madras)	7·87	14·45	18·27	31·80	3·56	24·05
Northerns (Andhra Pradesh)	7·49	19·81	19·00	24·73	3·26	25·71
285F (Punjab)	4·42	18·76	18·13	25·96	4·01	28·72
4F (Punjab)	6·71	20·73	17·50	20·96	4·63	29·47
Desi (Punjab)	6·78	17·64	14·38	21·67	4·73	34·84
U.S.A.	9·9	19·5	19·4	22·6	4·7	23·9

Analysis of some samples of cotton seed from some Provinces was done many years ago. But the first systematic analysis was carried out by Athawale (1944) on 88 samples of different *desi* and American varieties collected from 10 cotton-growing Provinces and States in undivided India and examined for moisture, husk, kernel, lint and oil contents and the results published in 1944. According to him, the average composition of Indian cotton seed was found as follows: moisture, 5.20-13.32 per cent.; lint, 0.02-3.25 per cent.; oil, 11.00-22.5 per cent.; husk, 37.00-54.00 per cent.; and kernel, 32.25-52.00 per cent. He also found that 74 per cent. of the samples analysed contained oil between 17.5-22.5 per cent. and 20 per cent. between 15.0-17.5 per cent.

A systematic and comprehensive analysis of 593 representative samples (354 *desi* and 239 American) of all the important varieties of *desi* and American type cotton seed produced in the 12 cotton-growing States of the Indian Union drawn from the seven successive harvesting seasons (1951-52 through 1957-58) was carried out at the Oil Technological Institute, Anantapur, from 1952. The latest official methods of the American Oil Chemists Society have been adopted in this work. The number of *desi* and American type seed samples analysed and thier distribution from the different States are given in Table 34.

TABLE 34. NUMBER OF DESI AND AMERICAN TYPE COTTON SEED SAMPLES DRAWN FROM THE DIFFERENT STATES DURING THE SEASONS 1951-52 THROUGH 1957-58 AND ANALYSED AT OIL TECHNOLOGICAL INSTITUTE, ANANTAPUR

State	Number of Desi type samples	Number of American type samples	Total Number of samples
Andhra	84	14	98
Bombay	78	22	100
Hyderabad	26	9	35
Madhya Pradesh	19	4	23
Madhya Bharat	21	15	36
Madras	38	73	111
Mysore	26	42	68
Pepsu	4	4	8
Punjab	13	24	37
Rajasthan	18	27	45
Saurashtra	8	1	9
Uttar Pradesh	19	4	23
	354	239	593

The 593 *desi* and American samples of cotton seed are classified according to their linter and oil contents falling under different ranges, as given in Table 35.

The composition and characteristics of the Indian cotton seed, as obtained in the above work on 593 samples (Desikan and Murti, 1953, 1954; Murti, 1956; Unpublished data) are given in Table 36.

For purposes of strict comparison of the composition of *desi* and American varieties on the one hand and the Indian seed as a whole and the United States seed on the other, the linters, oil and protein contents calculated on a 10 per cent. moisture basis are given in Table 37.

TABLE 35. ANALYSIS OF THE LINTERS AND OIL CONTENTS OF 354 SAMPLES OF DESI AND 239 SAMPLES OF AMERICAN TYPES OF INDIAN COTTON SEED

Limits of linters and oil content	Desi varieties		American varieties	
	Number	Per cent. of total samples	Number	Per cent. of total samples
Linters				
Below 3·0 per cent.	52	14·7	2	0·8
3·0—4·9 per cent.	112	31·7	7	2·9
5·0—7·4 per cent.	110	31·2	28	11·8
7·5—9·9 per cent.	55	15·6	94	39·5
10·0 per cent and above	24	6·8	107	45·0
	353	100·0	238	100·0
Oil				
Below 15·0 per cent.	23	6·5	7	2.9
15·0—17·4 per cent.	143	40·6	56	23·5
17·5—19·9 per cent.	157	44·6	124	52·2
20·0 per cent. and above	29	8·3	51	21·4
	352	100·0	238	100·0

TABLE 36. COMPOSITION AND CHARACTERISTICS OF 354 SAMPLES OF DESI AND 239 SAMPLES OF AMERICAN VARIETIES OF INDIAN COTTON SEED

Characteristics	Desi varieties		American varieties		Average of all varieties per cent.	U.S.A. seed	
	Limits per cent.	Average per cent.	Limits per cent.	Average per cent.		Limits per cent.	Average per cent.
Moisture	3·3-13·9	7·8	2·1-13·6	7·7	7·7	6·5-20·4	11·3
Linters	1·0-15·2	5·7	1·7-17·9	10·2	7·5	3·0-18·0	10·0
Oil	12·5-24·8	17·7	13·6-24·5	18·6	18·0	—	18·6
F.F.A. of oil in seed	0·6-10·4	2·1	0·4-8·6	2·1	2·1	0·5-9·6	1·3
Protein*	13·7-26·9	18·2	18·0-27·8	20·0	18·9	14·0-31·0	23·1
Seed size in mm.							
Maximum	6·8-9·2	8·1	8·1-10·5	9·3		8·0-12·0	—
Minimum	3·8-7·2	6·3	4·8-8·8	7·3			
Seed index** (Weight of 100 seeds in gms.)	3·9-12·6	5·6	4·7-10·9	8·0		—	11·1

* On dry basis of 47 *desi* and 29 American type samples only.

** Of 154 *desi* and 117 American type samples only.

TABLE 37. LINTERS AND OIL CONTENTS OF 354 SAMPLES OF DESI AND 239 SAMPLES OF AMERICAN VARIETIES OF INDIAN COTTON SEED ON 10 PER CENT. MOISTURE BASIS

Characteristics	Desi varieties		American varieties		Average of all varieties per cent.	U.S.A. cotton seed	
	Limits per cent.	Average per cent.	Limits per cent.	Average per cent.		Limits per cent.	Average per cent.
Linters	1·0-14·1	5·4	0·6-16·1	9·7	7·2	—	11·4-13·2
Oil	12·6-24·4	17·3	14·0-22·8	17·8	17·5	17·0-23·0	18·4-19·2
Protein	12·3-24·2	16·4	16·2-25·0	18·0	17·0	—	20·8

COTTON SEED PIGMENTS

The unique pigment system of the cotton seed kernels gives rise to many technical problems which do not occur in the processing of other oilseeds. Therefore, it is important to study the character and behaviour of these pigments at some length. The cotton seed kernel contains innumerable dark 'specks' which are actually pigment glands. They contain all the pigment materials which impart the yellow or red colour to the cotton seed meal and oil. The outer structure of the pigment gland is a more or less rigid wall rather than a membrane. The walls resist rupture under the pressure applied during the flaking of the seed. The gland walls are extremely sensitive to water and rupture in contact with water, with immediate discharge of the pigments. These glands are resistant to anhydrous organic solvents, but in the presence of water-miscible organic liquids or mixtures of organic liquids and water, the glands rupture, the speed of rupture increasing in proportion to the amount of water in the mixture. The effect of moisture on pigment glands increases at elevated temperatures. The principal pigment is gossypol which occurs in concentrations as high as two per cent. of the weight of the kernel. A number of other pigments both related and unrelated to gossypol and even some unidentified pigments occur in cotton seed.

Gossypol Content of Cotton Seed. The gossypol content of different samples may vary widely depending upon a number of factors including species, variety, location and year of growth, maturity, and length and condition of storage. However, a direct co-relation between the concentration of oil and gossypol is observed in mature cotton seed by a number of investigators. The ratio of oil to gossypol in the seed is quite variable, ranging from 55.1 to 35.1 in different samples of seed (Bailey, 1948g). Other pigments are usually present in lesser amounts than gossypol and these vary approximately in the same way and appear to be influenced by the same factors as gossypol. The gossypol contents of nine varieties of Indian cotton seed, their kernels and the crude oil obtained there from by a laboratory hydraulic press, was reported by Narayana Rao and Krishna Murty, 1954 as varying from 0.72 to 0.92 per cent. in the seed, 1.56 to 2.35 per cent. in the kernel and 0.38

to 0.47 per cent. in the oil. Examination of 18 samples of different *desi* and American varieties of cotton seed at the Oil Technological Institute, Anantapur, has shown that the gossypol content of the cotton seed varies from 0.43 to 0.88 per cent., in the kernels from 0.84 to 1.68 per cent., and the total gossypol of the corresponding oils 0.04 to 0.80 per cent. on dry basis (Desikan, Rao and Murti, 1957). The screw press cake obtained in the pilot plant work of the Institute (12 samples) of the above seed varieties and from mills (four samples) contained free gossypol varying from nil to 0.09 per cent. The gossypol content of the United States cotton seed are reported as varying from 0.44 to 0.76 per cent., kernels of varieties grown at 13 localities from 0.39 to 1.70 per cent., the total gossypol of the screw pressed oil from 0.25 to 0.47 per cent. (Pons *et al.*, 1953, 1957) and of the hydraulic and screw pressed meals from 0.02 to 0.25 per cent. (Bailey, 1948i). The gossypol content of the U.S.S.R. seed is reported as varying from 0.15 to 1.59 per cent. (Bailey, 1948e,h). The highest gossypol content of any cotton seed reported is that of Egyptian and Sea Island varieties (*Gossypium barbadense*). Boatner *et al.*, (1949) reported that the gossypol content of different varieties of *G. barbadense* varied from 1.92 to 3.35 per cent. on the weight of kernels, while those of *G. hirsutum* (U.S.A. seed) varied from 1.38 to 2.12 per cent.

Composition and Properties of Gossypol and Gossypol Like Pigments. Gossypol and most of the other cotton seed pigments are complex polyphenolic compounds having the molecular formula $C_{30}H_{30}O_8$, which are very unstable and are readily converted into deeply coloured degradation products. But the complete structure and the molecular formula of gossypol have not yet been established beyond doubt. Gossypol is a yellow solid which has been reported to be soluble in methanol, ethanol, isopropanol, ether, acetone, glycerol, cyclohexane, and high boiling petroleum naphtha (b.p.60-110°C.) and insoluble in low boiling petroleum naphtha (b.p.30-60°C.) and water. When heated, gossypol melts with decomposition, its meltng point being differently given by different workers as 184°, 199°, and 214°C. It is unstable in solution at room temperature. The compound undergoes a variety of reactions with the various reagents. It reacts as a strong dibasic acid forming neutral disodium and dipotassium salts which are coloured deeper yellow than the free compound. It is readily soluble in dilute aqueous sodium hydroxide, potassium hydroxide and sodium carbonate. Ethyl alcohol solution of gossypol and ethyl alcohol and water solutions of its alkali and alkaline earth salts are extermely sensitive to oxidising agents. It reacts with organic basis, such as aniline and pyridine and with liquid ammonia to form non-ionic compounds of widely different stabilities. With carbonyl reagents, gossypol forms a stable dioxine, dihydrazone, etc.

There are a number of other pigments related to gossypol occuring in the pigment glands of cotton seed kernel, including the purple coloured gossypurpurin, the blue coloured gossycaerulin and the orange coloured gossyfulvin.

More recently, evidence has been obtained of the presence of 11 other pigments, in addition to gossypol, in pigment glands. All these pigments are even more unstable than gossypol and readily undergo alteration. All these intraglandular pigments undergo alteration within the seed even during storage of normal seed at moderate temperatures and in the absence of excessive moisture. The pigments of immature and of moist cotton seed vary even more widely during storage of the seed, increasing with the period of storage. Also, due to oxidative changes taking place in the pigments of the seed by exposure to the action of air during storage, the oil in the seed gets darker on storage, probably due to the partial conversion of polyphenolic pigments into more deeply coloured quinoid compounds.

Cotton seed pigments have toxic physiological effect on certain types of animals when taken in appreciable quantities. Although cattle and sheep can consume large quantities of raw cotton seed continuously without any detectable ill-effects, rabbits, guinea pigs and swine will die within a short time if they eat very much of it. Investigations made in the United States (Withers and Carruth, 1915; Schwartze and Alsberg, 1924) have shown that purified gossypol has poisonous effect on these animals. During the processing of cotton seed by hydraulic or expeller pressing, the cooking or moist heat treatment given to the kernels causes changes to take place in the material which largely inactivate the gossypol. It is postulated that the inactivation of gossypol is due to its combination with some of the cotton seed protein. On this basis, the inactivated gossypol is often referred to as 'bound' gossypol. The amount of free or unchanged gossypol in commercial cotton seed cake, while relatively small in comparison with raw cotton seed, varies from sample to sample. The other cotton seed pigments also seem to behave similarly, on cooking, as gossypol.

The pigmentation of the oils obtained by different methods of processing is different. This is due to the different conditions of cooking and heat treatment received by the meats and oil in the different methods. Thus, while the pigmentation of the meals obtained by the two methods of hydraulic and expeller pressing are found approximately to be the same, the principal pigment of the crude screw pressed oil was entirely different from that of the crude hydraulic pressed oil. It was also found that the pigmentation of the processed oil was largely determined by the original pigment content of the seed. The pigmentation of the crude oil extract of solvents will depend upon the nature of the solvent, the amount of moisture it contains and the extent to which the oil is heated in order to remove the last traces of the solvent from it. Some oils are darker and some lighter than the screw pressed oils.

Other (Extra-Glandular) Pigments. These are mainly oil-soluble compounds of the extra-glandular tissues. These comprise of carotenoids, chlorophyll, flavones and pigments of unidentified nature, which occur in the kernel outside the pigment glands. Palmer and Eccles (1914) reported the occurrence of carotene and xanthophylls in cotton seed. The carotenoid pigments content of different samples of cotton seed was reported to vary from 0.096 to 0.219 per cent. (Bailey, 1948f). The content of carotenoid pigment was found to be greater in immature than in mature seed, but it was present in all expressed and solvent extracted cotton seed oils which were examined. This pigment is completely soluble in petroleum naphtha. Very little of this pigment is removed from the crude oil during alkali refining. The presence of small amounts of chlorophyll in cotton seed extracts and oils has been reported occasionally.

A colourless precursor of chlorophyll is detected in the walls of the protein cells of the seed kernel. Flavone and other pigments of an unidentified nature are also reported to be present in the cotton seed.

OTHER MINOR CONSTITUENTS OF COTTON SEED

Phosphorus-containing Compounds. Phosphorus content in six samples of cotton seed kernels from central Asia and the Caucasus was found by Lishkevich (1937), to vary from 0.8 to 1.0 per cent. He found that 75 per cent. of the phosphorus in cotton seed kernels is present as phytin, five to six per cent. as phosphatides and the balance as phosphoproteins and insoluble fraction. It was also reported that 5.2 per cent. of the total phosphorus in ether-extracted cotton seed meal was present as inorganic phophorus. A somewhat higher amount of phosphorus content of 1.79 per cent. was found in the kernel of a cotton seed grown in the United States (Bailey, 1948 l). The phosphatides of cotton seed are found in both the oil and the meal. The amount of phosphatides which is extracted with the oil depends upon the method of pressing or extraction and on the pre-treatment of the seed, particularly on the adjustment of its moisture content. The phosphatides from cotton seed contain chiefly lecithin and cephalin.

Mineral Constituents. The mineral constituents of cotton seed are important both from the standpoint of the fertiliser requirements of the cotton plant and the value of cotton seed meal as a fertiliser, as well as from the standpoint of the nutritional value of cotton seed meal as a feed and of cotton seed flour as a food. The ash content of cotton seed represents the sum total of the metallic oxides of the mineral constituents of the cotton seed. The ash content varies from 3.26 to 4.95 per cent. in the Indian cotton seed samples examined (Table 33). The mineral constituents reported are those of phosphorus and potassium (1.27 per cent. of P_2O_5, and 1.17 per cent. of K_2O), sodium, calcium, magnesium, iron, silicon, alluminium, among others. The first two occur in significant quantities and the rest in smaller amounts.

Sterols. The unsaponifiable matter of cotton seed oil occurring in the kernel of the seed, contains sterols, tocopherols, hydro-carbons, etc. Kaufman (1941) reported that crude cotton seed oil may contain up to 1.6 per cent. sterols. The mixed sterols were found to consist predominantly of β-sitosterol and small amounts of ergosterol which is pro-vitamin D,

Anti-oxidants. Extracts obtained from cotton seed meal by treatment with various solvents were found to have marked anti-oxidant activity (Hilditch and Paul, 1939). Gossypol occuring in the seed has strong anti-oxidant properties. Tocopherols are the other natural anti-oxidants present in the seed, while the phosphatides in the cotton seed, acting as synergists, enhance the anti-oxidant activity of tocopherols. Crude cotton seed oil is found to be very stable on account of the presence of these anti-oxidant materials in it.

Vitamins. Cotton seed contains the oil soluble vitamins A, D and E, which accompany the oil and the water soluble vitamins B complex and C, which remain in the meal in the processing of the seed.

The vitamins are of interest in relation to the nutritional value of the cotton seed oil, meal or cake and flour. Crude cotton seed oil is a relatively good source of vitamin E and is reported to contain 0.10 to 0.14 per cent. of total tocopherols (vitamin E) and refined oil 0.08 to 0.12 per cent. It also contains ergosterol, which is a pro-vitamin, being converted into a form of vitamin D upon irradiation with ultra-voilet light. Carotene (pro-vitamin A) is also present in the oil. Cotton seed is a good source of thiamin, riboflavin, choline and a few other components of vitamin B complex (Bailey, 1948 k, m).

CHARACTERISTICS OF INDIAN COTTON SEED

From the foregoing information and data given in Tables 35, 36 and 37, it will be seen that *desi* and American types of Indian cotton seed exhibit striking differences in some of the characteristics. Thus, the size of the American type seed is bigger and the linters, oil and protein contents higher than those of *desi* type seed. The closer lower limits of size of 3.8 and 4.8 millimetres, respectively, for *desi* and American type seed is presumably due to the almost invariable admixture of the American type seeds with some *desi* type seeds in trade practice. While the differences in the size and the lint content are marked, the difference in protein content is less marked and in oil content still less marked, since the difference in the average protein contents is 1.6 units and in oil contents only 0.5 units, on a common 10 per cent. moisture basis (Table 37). Data in Table 37 reveal that many varieties of *desi* type seed contain quite significant quantities of linters and oil which in many cases exceed those of the American type seed (though many more of American type seed samples contain more oil than *desi* type seed). There is practically no difference in the range and average moisture contents of *desi* and American type seed. The differences between the Indian *desi* seed and the North American (U.S.A.) seed are even more marked than those between *desi* and American type Indian seed in all respects, mentioned above. The American type Indian seed is somewhat midway in its characteristics between *desi* type seed and the United States seed.

From (page 161), it will be seen that on the whole, the gossypol and other pigments content of the Indian cotton seed is somewhat higher than that of the United States seed, excepting for *Gossypium barbadense* species of Egyptian and Sea Island varieties. The observed darker colour of the Indian crude cotton seed oil than that produced in the United States can perhaps be attributable to this as well as to the imperfect processing of cotton seed done in India at present. The moisture content of the Indian seed is, in general, less than that of the seed produced in the United States. Therefore, the problem of deterioration of the seed on storage seems to be less acute than that in the United States. Further, the kernel content of the Indian seed of both *desi* and American types is less (44.0 to 52.5 per cent.) than that of the United States seed (51.3 to 59.3 per cent.), while the hull (fuzzy) contents of the Indian seed is higher than that of the United States seed.

STORAGE OF COTTON SEED

GENERAL

The changes taking place in cotton seed during storage are of considerable importance, for as a result of the biological activity in cotton seed in storage, substantial losses are sustained by the cotton and cotton seed oil industries. The cotton seed, which is reserved for replanting, must be protected from the loss of viability and vigour till the succeeding planting season. The atmospheric temperatures and humidity in several localities are such as to cause a high mortality in the stored seed and consequent increased cost of cotton production. The biological changes which take place in the surplus seed intended for feed and industrial uses are of no less importance. Excessive biological activity in the seed either in the field prior to harvesting or subsequently during the storage will result in a reduction in the quality of both the oil and the meal.

Studies made on the factors that affect the viability of cotton seed on storage revealed that the moisture content of the seed during storage and the temperature of storage play an important role. Storage under conditions of both high moisture and extreme desiccation is harmful to the longevity of the seed (Phillis and Masou, 1945). The seeds stored at extreme temperatures also suffer in their viability. Optimum conditions of storage were observed to be in the range of 20 to 40 per cent. relative humidity, corresponding to a moisture content (wet basis) in the seed of five to seven per cent. Seeds for planting are commonly stored in jute (hessian) bags so that the air around the bags is circulated to minimise extremes of high humidity and temperature.

Moist cotton seed, when stored in bulk in the mill ware-houses, will heat relatively rapidly and seed temperatures as high as 190°F. have been recorded in the United States. Such high temperatures may result in damage not only to the seed but also to the seed house. But by far the greatest loss results from the damage to the seed through acceleration of biological processes which proceed more rapidly at elevated temperatures. Heating accelerates damage due to oxidation of the pigments, lipolysis (hydrolysis of glycerides to form free fatty acids), protein deterioration, loss in viability, etc. In the heating process during storage, no oil or proteins are consumed. Though there is no overall loss in nitrogen, the proteins are partially hydrolysed and are denatured. The quality of the oil is deteriorated by an increase in free fatty acids, setting in of rancidity and darkening of the colour. In addition, it has been shown that there is a decrease in organic phosphorus. The principal difference between the chemical changes which take place during germination and those that occur during heating is that the oil content decreases during germination where as it remains constant during heating (Bailey, 1948c).

Researches carried out in the United States (Bailey, 1948b) show that the optimum conditions for lipolysis comprise both a high temperature and a high moisture content. In the process of increasing the temperature, conditions favourable to lipolysis and other disintegrative activities are created. Unless the treatment is rapid and completely effective, the seeds may be left in a condition more favourable for increased than for lowered biological activity. On the other hand, lipolysis can be avoided or at least minimised by storing the seeds at very low temperature, i.e., near freezing.

Cotton seed contains certain enzymes, such as lipase, catalase and peroxidase. The biological activity (respiration) of these enzymes increases with the increase in the moisture content of the seed and can be observed and measured in the resting seed by the production of heat. The rise in respiration is a regular function of the moisture content. With a rise in temperature, the intensity of respiration of the enzymes also increases up to a certain limit. This increased biological activity results in rapid lipolysis taking place in the seed, both the biological activity and the lipolysis increasing with the length of its storage. Immature seeds apparently respire at a higher level of intensity than mature seeds of equal moisture content. The rate of lipolysis in the immature seed is very high at the beginning of storage and decreases gradually, whereas in the normal seed, appreciable lipolysis commences only after several months of storage.

Lipolysis is facilitated by mechanical disintegration of the seeds. It was found (Bailey, 1948d) that for about the same range of moisture content, the ground meats have the highest rate of lipolysis, flaked meats, which are not as highly disintegrated as ground meats, manifest less lipolytic activity, while the whole meats undergo lipolysis less readily than flakes, but more readily than the whole seed in which the rate of lipolysis is the least.

FIELD DAMAGE AND STORAGE DAMAGE

Two types of deterioration of cotton seed are recognised, viz., field damage and damage in storage. The field damage is the result of unfavourable weather conditions during the period of boll opening. Freshly opened cotton bolls have a moisture content of about 50 per cent. which may decrease to about 10 per cent. in 10 days under ideal weather conditions. If, however, there is rainfall and high humid conditions prevail during the ten-day period following the opening of the bolls, field damage will result. Also, if the rate of loss of moisture is greatly reduced or if there are recurring rains so that the moisture content of the seeds alternately increases and decreases during that period, field damage will result. Field-damaged seeds may have a prime colour, whereas, storage-damaged seeds are invariably discoloured. Field-damaged seeds have a greenish background colour (prime seeds have a creamy white background colour), while storage-damaged seeds are characterised by a background colour ranging from light brown to almost dark. Both types yield oil having a higher content of free fatty acids than do prime seeds. Field-damaged seeds do not generally yield as discoloured an oil as that obtained from storage-damaged seeds.

It has been suggested that cotton harvested during rainy and highly humid harvesting season should be dried before ginning and the ginned seeds should again be dried before storage, because the drying of the seed cotton has little effect upon the moisture content of the seed (Rusca and Gerdes, 1942).

Conditions prevailing in storage are quite different from those prevailing in the field. In the field, the temperatures remain close to that of the atmosphere, whereas in storage, due to the heaping of the seed and the insulating effect of the surrounding lint on the seed, temperatures may become markedly higher. At these higher temperatures, the seeds exhibit more vigorous respirations, which in turn results in increased temperature and a more vigorous lypolysis.

One of the difficulties involved in the prevention of storage damage is the inability of the mill operator to predict accurately the future behaviour of the seed on the basis of the usual analysis made when the seed arrives at the mill. The moisture content alone does not provide sufficient information for prediction of storage behaviour. Robertson and Campbell (1933) have stated that cotton seed containing less than 10 per cent. moisture (wet basis) can be safely stored, cotton seed containing 10 to 14 per cent. moisture may or may not deteriorate, depending upon other factors and those with more than 14 per cent. moisture content will deteriorate. It is also felt that micro-organisms may constitute a factor in the storage damage of cotton seed with moisture content higher than 15 per cent., although the principal deteriorative process is considered to be due to the activity of the enzyme systems within the seed. In some cotton growing areas, pink bollworms cause serious damage to the cotton seed. This can be effectively prevented by sterilising the seed (by steam, or otherwise) to a temperature range of 150° and 165°F. for 30 seconds.

STORAGE CONDITIONS OF COTTON SEED IN UNITED STATES

Considerable care and attention is given to the proper storage of seed in the mills. Because of the large capacity of mills and fast movement of the seed in the season, the seed delivered in trucks or cart loads, is weighed by weighing machines with automatic weight recording mechanism. The seed is unloaded either by pneumatic unloaders (creating suction through a tube over the seed) or by dumping it into a large pit and conveying it into the mill by screw conveyors or by a power showel, which drags the seed out of the truck and into the pit. By these devices, a tonnage ranging from 400 to 2,800 can be unloaded in 24 hours.

All the mills grade the cotton seed received by them. Representative samples are taken with the aid of the prescribed sampling tools and procedures and these are analysed by the chemist licensed by the United States Department of Agriculture. Certificates of the grade are then given. Grading attempts to evaluate the seed before milling, by determining the percentage of oil, ammonia, moisture, foreign matter, linters and free fatty acids in the seed. A combination of these items helps to arrive at the net quantity and quality index and determine grade. The seeds of similar grades are stored together in different sections to facilitate processing and to prevent the admixture of good and poor quality seed, which will yield a lower grade oil.

For proper storage, both moisture content of the seed and temperature are of prime importance. The moisture content of the seed is the most viatl factor in storage because the high moisture seed will heat and cause rapid deterioration in quality. Most of the mills believe that seed can be safely stored if the moisture content is not over 10 to 12 per cent., depending upon the temperature. During critical periods, the temperature may be recorded daily or two to three times a week, or once a week. Some start conditioning the seed by pulling air through it with large fans when the temperature approaches 180°F., and others do it when the temperature reaches even 100°F.

In most areas, cotton seed is stored in buildings with concrete flooring to prevent deterioration. The modern building for storing seed has a steel frame covered with galvanised iron on sides and roof. The floor is concerte, the sides are vertical for about 12 feet and the slope of the roof is 45°. In filling the house, inclined drag conveyors elevate the seed to the top of the house. Screw conveyors then carry the seed across the top of the house and drop it through the centre of the building. Such houses fill to the top because seed, as it falls, takes the same slope as the roof. A tunnel, along the floor, running to the full length of the house, with tile laterals about every eight feet, makes it possible to pull air through the seed, in case the temperature becomes too high. This type of house can also be used as a general warehouse when not being used for cotton seed, say, for storing linters, meal or hulls.

Some mills use cylindrical tanks or silos mostly made of steel, for seed storage. These silos have a capacity ranging from 500 to 4,500 tons each. Seed is put into the silos by blowing, by screw conveyors or by bucket elevators. Arrangements are also made to move the seed to reduce the temperature, whenever desired. When their closed storage is insufficient, some mills in certain localities (West Texas, for instance) store their seed outside and cover it by tarpaulins.

The total amount of storage needed by mills is estimated to be about 70 per cent. of their total crush.

The following steps are taken to reduce the damage on storage of seed in the United States:

1. Pre-drying of the seed prior to storage.
2. Forced aeration during storage.
3. In the case of storage in silos, moving the seed by rolling them, thus exposing them to air.
4. Chemical treatment of the seed to inhibit the biological activity within the seeds. Although numerous attempts have been made to inhibit the deteriorative action of the enzyme systems by several chemicals which proved partially successful in the laboratory and pilot plant experiments, the process has not yet been found commercially successful and has not yet been adopted on a large scale.

STORAGE CONDITIONS OF COTTON SEED IN INDIA

From the information collected from 20 cotton seed crushing mills in India (out of 35 addressed) by the Oil Technological Institute, Anantpur, the storage conditions of cotton seed are found to be as given below.

Cotton seed is invariably unloaded at the mills and also moved into storage place by manual labour and no mechanical devices are employed. The seed is stored in separate godowns, mostly in jute bags piled up in rows or heaped in a few cases in a loose condition. The majority of the godowns in which the seed is stored are closed *pucca* built godowns, without much access to air or light, but in some mills, the godowns are well ventilated.

A few mills also stock the seed in the open, either in gunny bags or in loose heaps. Quite a few mills stock the seed in the open in heaps covered by tarpaulins, when their godowns are full. One or two mills reported that they stock the seed only in the open compound.

The mills stock the seed for periods varying from one month to a maximum of 10 months, but the majority stock the seed for three to six months. The flooring of the godowns in most of the mills is not *pucca* and several mills have corrugated zinc sheet roofing for their godowns. Drying of the seed is not done prior to storage, nor is any forced aeration practised. No arrangements are made to note rise in temperature regularly. Most of the mills do not even observe the temperature of the stored seed. A few mills stated that they occasionally observed a small rise in temperature. A few other mills said that they had not found any increase in the temperature.

No systematic analysis is done at the mills on receipt of the seed nor is any grading made before the seed is stored. The seed is not tested during the storage period either. Many of the millers are generally not aware of the possibilities of the damage to seed during storage. However, two factors seem to help in lessening the damage of cotton seed in India under the above conditions. Due to the storage in bags, air circulates around them and inside the bags. Secondly, the moisture content of the Indian seed is generally less (2 to 14 per cent.) than in the United States (6.5 to 20 per cent.) at the time of receipt at the mills. Hence the heating of the seed and the consequent storage damage appears to be less in India than in the United States.

Though considerable volume of research was conducted on the storage of cotton seed in the United States, very little information is available in India on the proper storage conditions of cotton seed. Some work has recently been undertaken in this direction at the Central Laboratories for Scientific and Industrial Research (now Regional Research Laboratory), Hyderabad, and the Oil Technological Institute, Anantapur. In the former laboratories, studies on the storage of the Parbhani-American variety of cotton seed at different humidities and temperatures was made (Harwalkar *et al.*, 1958). The results indicate that the viability of the seeds is decreased as the F. F. A. increases, that the peroxide value of the oil in the seed does not alter appreciably and that seeds stored in gunny bags at room temperature show an increase of only three units. The period of storage is not mentioned. At the Oil Technological Institute, Anantapur (Murti, 1956 a), in one case, Laxmi (American) seeds from Mysore and Red Northern (*desi*) seed from Andhra Pradesh were stored in gunny bags at room temperature, varying from 87° to 78°F. for three months. Subsequently in a second case, Laxmi seeds from Andhra Pradesh were stored in gunny bags: (*i*) at room temperature (varying from 80° to 106°F.); and (*ii*) at low temperature (40°±2°F.) for a period of one year. In all cases, no change in the oil content of the seed was observed, but the moisture content of the seed varied irregularly. The free fatty acids increased from 0.85 per cent. to 1.25 per cent. in Laxmi seed and from one to two per cent. in Red Northerns in the first case, at room temperature, in three months. No rise in temperature of the seed over the surrounding laboratory temperature was noticed. In the second storage experiment, the free fatty acids in the seed stored at cold and room temperatures varied respectively, from 0.8 per cent. to 1.4 per cent. and 0.8 per cent. to 1.8 per cent. The Lovibond colour of the crude oil in Laxmi seed, measured in a 1/4 inch cell increased from 103 (Y+10R) to 153 (Y+10R) units in cold storage and 103 (Y+10R) to 161 (Y+10R) units at room temperature.

A thorough study on storage damage of the Indian cotton seed, under both controlled and mill conditions, should be made for the guidance of the industry.

PROCESSING OF COTTON SEED

Before oil is extracted, the seed should be cleaned, delinted, hulled and the meats rolled and cooked. A typical diagram of the process is given in Figure 23.

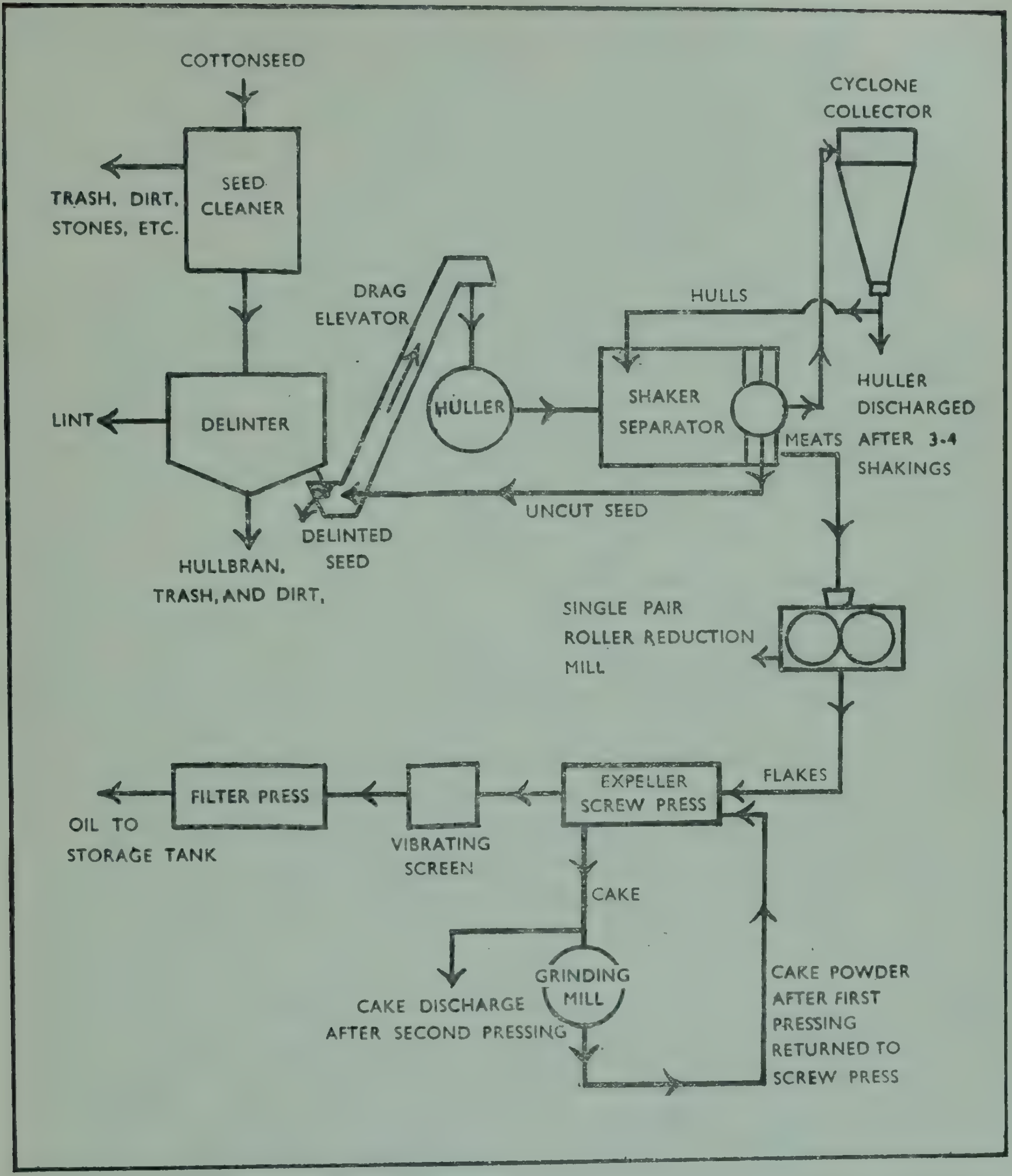

COTTONSEED
SEED CLEANER
TRASH, DIRT, STONES, ETC.
DELINTER
LINT
HULLBRAN, TRASH, AND DIRT.
DELINTED SEED
DRAG ELEVATOR
HULLER
SHAKER SEPARATOR
HULLS
CYCLONE COLLECTOR
HULLER DISCHARGED AFTER 3-4 SHAKINGS
MEATS
UNCUT SEED
SINGLE PAIR ROLLER REDUCTION MILL
FLAKES
EXPELLER SCREW PRESS
VIBRATING SCREEN
FILTER PRESS
OIL TO STORAGE TANK
CAKE
GRINDING MILL
CAKE DISCHARGE AFTER SECOND PRESSING
CAKE POWDER AFTER FIRST PRESSING RETURNED TO SCREW PRESS

Fig. 23. Flow Diagram of Cotton Seed Processing

Seed Cleaning. Cotton seed moves into the cleaning room either directly from the seed house or from the intermediate seed tanks which are filled with the seed earlier to ensure an uninterrupted flow of the seed into the mill. The seed must be cleaned because it usually contains considerable amounts of trash, such as leaves, twigs, bolls, hulls, stones, sand, cotton burrs, dead seed, nails, bolts and other foreign material. If this foreign matter is not removed, it causes undue wear and tear of the machinery, discolours lint and reduces the quality of oil and cake (Plate XVII).

Two types of equipment, the revolving screen and the shaker screen types, are used. Individual mills modify machinery and change the process to suit their own conditions. The shaker screen is the most common type used. It consists of a perforated metal platform set on an incline. Its shaking motion causes the seed to move down and the foreign matter passes through the perforations. Blowing or suction fans are usually fitted in the equipment to assist the separation of the lighter material. Magnets are also used to remove any metal that could cause fire or damage to the machinery.

Delinting. The second step in the pre-treatment is delinting. The short linters left on the seed coming from the gins, which may be up to 18 per cent. of the total weight of the seed, are removed by machines known as delinters (Plate XVIIIa) and the product removed is known as 'cotton linters'. Delinters closely resemble the saw-type gins, the principal difference being in the number of saws per stand. In a cotton gin, the number of saws per stand ranges from 70 to 90, with most gins having 80. In oil mills, the number of saws per stand ranges from 106 to 176, with most mills having 141 or 176. The saws are sharpened once every 24 hours on automatic filing machines (Plate XVIIIb). Each stand has a roller with a series of circular saws projecting through a set of steel ribs. As the seed falls on the ribs, the saws revolve, cutting the fibre short and carrying them through the ribs. The seed, too large to pass through the ribs, falls down and is conveyed to the huller unit. The fibres are removed from saws either by a cylindrical brush revolving with the saws at a somewhat higher speed or by an air pick-up (pneumatic) system. The usual practice is to run the seed through a part of these machines to produce what are known as 'first cut' linters and through the remaining machines to produce the 'second cut' linters. Sometimes, only a single cut is made, producing 'mill run' linters. A new practice among some mills is to make a 'third cut' or even more. The 'first cut' linters consist of the longer fibres on the seed and additional cuts consist of shorter fibres. The amount of lint removed in the different cuts depends upon the market demand and prices for various grades of linters. Usually about two per cent. lint is left on the seed to facilitate the separation of hulls from meats in the subsequent operation. The capacity of each delinter varies from four to eight tons of seed per day with an average of about five tons, depending upon the amount of lint on the seed, the amount of lint removed and the number of saws.

The linters are taken from linter machines through lint beaters and cleaners to the bale press where they are compressed, wrapped and tied into bales.

Hulling. The next step is to remove hulls which surround the kernels or meats of the seed. Seed moves either directly from the delinter room or through an intermediate storage tank to the cotton seed huller. Two types of hullers, the bar huller and the disc huller, are used. The bar huller is considered to give slightly better results than the disc huller and is more commonly employed. The bar huller contains a series of knives that cut the hulls and loosen them from the kernels or meats. The disc huller, on the other hand, functions through the operation of one stationary and one rotating disc upon the face of each of which are cast bars or ridges with cutting edges radiating from the centre. The faces of the two plates being concave, the seed enters freely at the centre and then travels centrifugally outward through a gradually narrowing space between the discs. The seeds are cleanly cut at the periphery between the stationery and rotating sharp edges. In either unit, the seed is cut coarsely to avoid oil absorption by hulls. Either unit has a high capacity to handle the seed (Plate XIX).

The coarsely cut seed from the huller falls on a shaker separator (on which the huller is mounted). The free meats are shaken out as the material passes over the shaker separator. The fine meats fall below through the screens and are added to the main stream of meats. The coarse meats pass through the screen on to the one below and are collected separately. As the uncut seed and the hulls pass over the end of the screen, the hulls are aspirated and collected into a cyclone and the uncut seed passes over and is returned to the huller. The hulls are passed through a hull beater to remove from them fine, floury meats. The separation process of the hulls from the meats, so as to give a cake of 41 per cent. protein, is a complicated one and needs experience in handling it properly.

There are many variations of details in the hulling processes, which fall into the general classification of: (*i*) double hulling; (*ii*) single hulling; and (*iii*) universal hulling. In double hulling, the entire tonnage of hulls passing over the first-cut shakers and hull beaters is again passed through the second-cut hullers, which have a very close setting. Consequently, the hulls are exposed to oil absorption a second time in hulling the uncut seed. Secondly, the double hulling process produces a large amount of fine hulls in the second hulling due to the close setting of the huller. These fine hulls are inclined to pass through the perforations of the shaker and are difficult to separate from the meats. These two disadvantages are avoided in the single hulling process, where the seed is passed through a huller, cutting approximately 80 to 85 per cent. of the seed in the first pass. The cut seed is then put over a shaker-separator to remove the free meats. The hulls and uncut seed are either passed through a hull beater to remove the meats sticking to the hulls and then through a hull and seed separator to remove the uncut seed, or through a combined shaker and a hull and seed separator unit followed by a hull beater through which the hulls pass before they go to storage. The method of universal hulling is a combination of the single and double hulling. This modification of the process can be used advantageously in special cases where: (*a*) a large amount of lint is left on the seed and a relatively low potein cake is required; and (*b*) where the seed contains a large proportion of immature seed.

In the opinion of the author, the single hulling process, using a hull beater, gives the best results for processing Indian cotton seed. Secondly, the screens of the separator, where the principal separation is usually accomplished with 7/32 inch round perforated metal for the larger American type seed, should be replaced by a perforated screen of smaller holes (5/32 inch), while processing *desi* variety seed.

Rolling Cotton Seed Meats. Cotton seed meats obtained in the hulling operation are rolled or flaked usually by a five high heavy steel rolls. The important point is that rolling must produce uniform thin flakes; otherwise, cooking and subsequent processing cannot be effective. The meats should be flaked to a thickness of approximately 0.010 of an inch for best results, whether the cells are actually ruptured in this process as some observers have shown (Lamborn, 1920; Goldovskii and Podol'skia, 1934; Shchepkina, 1934; Heublyum and Zaphe, 1935) or whether they are not ruptured but only exposed to the surface to be easily ruptured in the subsequent process of cooking as some others have found (Thornton, 1932; Woolrich and Carpenter, 1935). In order to produce satisfactory flakes, a certain amount of moisture is necessary. If the meats are too dry, sufficient moisture must be added before rolling to produce proper flaking. This is usually done in the mills by running a controlled stream of water into the meats before they fall on to the rolls. The optimum moisture content of rolled flakes should be 10 to 12 per cent.

Cooking of Meats. Whatever equipment or method of extraction is used, cotton seed meats (flakes) will have to be cooked or tempered in suitable equipment. The objects of cooking, according to the consensus of the investigators on the subject, are the folowing (Bailey, 1948 n).

1. To rupture or finish rupturing of oil cells.
2. To increase the fluidity of the oil by increase in temperature.
3. To coagulate or granulate the protein aleurone grains so as to facilitate the separation of oil from proteinaceous and other materials.
4. To precipitate phosphatide material in order to produce oil of lower refining loss.
5. To dry the cooked meats mass to a proper moisture content, optimum for oil extraction. This prevents 'crawling' of wet meats or crumbling of dry meats.
6. To detoxify free gossypol by causing this material to diffuse from the resin glands and combine with the protein material to form inert nontoxic 'bound' gossypol.
7. To destroy moulds and bacteria.

Cooking, however, has the disadvantage of darkening of the oil and the cake through diffusion of colouring materials from the resin glands and also denaturing the proteins to some extent.

The equipment employed for cooking cotton seed meats in oil mills depends upon the method of extracting the oil. For hydraulic pressing, usually a stack cooker is used. For expeller (screw press) pressing, the cooking and tempering equipment built over the modern expellers is used and in the case of solvent extraction either a stack cooker or other type of conditioner is used.

The stack cooker generally used consists of four or five individual kettles or sections of 72 to 84 inches inside diameter and about 28 inches high. The kettles are steam-jacketted both on the sides and at the bottom. Each kettle contains an agitator arm with attachments designed to mix the meats constantly for efficient transfer of heat from the steam-jacketted walls and the bottoms to the meat mass. The kettles are fitted with quick-closing gates, which by operating the corresponding levers open when meats in the kettle fall into the one below. By adjustment of the steam pressure, agitator speed and height of meats in the kettle, it is possible to obtain a wide range in the meats' temperature in the kettles. Devices are also provided to inject a fine spray of water in the top kettle. To show the moisture and temperature conditions in the various kettles, indicators and recording instruments have been fitted to the kettles.

The optimum conditions of cooking the meats for hydraulic press operation are, starting with flakes with a moisture content of 11 to 12 per cent. to reduce it to a final optimum moisture content of 5 to 5.5 per cent., a temperature of 170° to 180°F. in the top kettle, increasing it gradually in successive kettles with a final finishing temperature of 235°F. and a total cooking time of 80 to 120 minutes, depending upon the condition of the meats (prime meats for a longer time and high free fatty acid and damaged meats for a shorter time).

The optimum cooking conditions for expeller pressing and solvent extraction are different. These are discussed under the corresponding processes.

Methods of Extraction. Three principal methods are used for the extraction of oil from cotton seed. But regardless of the method of extraction, all the processing steps for cotton seed through the hulling operations are the same. The oldest of these is the hydraulic pressing. The next to come into existence is the screw press (expeller) process and a more recent method of extraction is the chemical or solvent process. Some mills are now using a combination of screw presses and solvent extraction called pre-press solvent extraction. The latest development is a modification of solvent extraction known as filtration extraction. It should be pointed out here that no one method excels others in every phase or respect. In the United States, where cotton seed processing industry has developed to the greatest extent and where all the above methods are adopted, during 1952-53, 5.5 million short tons of seed were processed for oil. Of this, 46 per cent. was by hydraulic methods, 33 per cent. by screw press method, 9 per cent. by the solvent extraction method and 12 per cent. by the pre-press solvent extraction method (Fetrow *et al.*, 1956).

Hydraulic Pressing. This was the most important method extensively in vogue in the United States till recently and still continues to be the method by which the largest quantity of seed is processed. This method does not appear to have been adopted for crushing cotton seed in India.

From the cooker, measured quantities of meats are wrapped in press cloth, and pressed slightly, in the cake-former, to form a cake which can be conveniently handled and is of proper size for the press box or cage. The hydraulic press consists of a series of rectangular steel boxes, one above the other, each of which is perforated on the bottom. When cakes are placed in the boxes, pressure on them is gradually increased through the medium of a hydraulic ram, to around 5,000 pounds per square inch, in two stages, to squeeze oil from the flakes. The pressure is maintained from 30 to 45 minutes. After the pressure is released, the cake is released, the cake is removed from the cage and a fresh charge made. The oil left in the cake by this process is five to six per cent. of weight of the cake.

Screw Pressing. The advantages of screw pressing over hydraulic pressing are saving in labour costs, increased oil yield and no cost for press cloth. The principal disadvantages are higher initial cost, repair costs and power consumption.

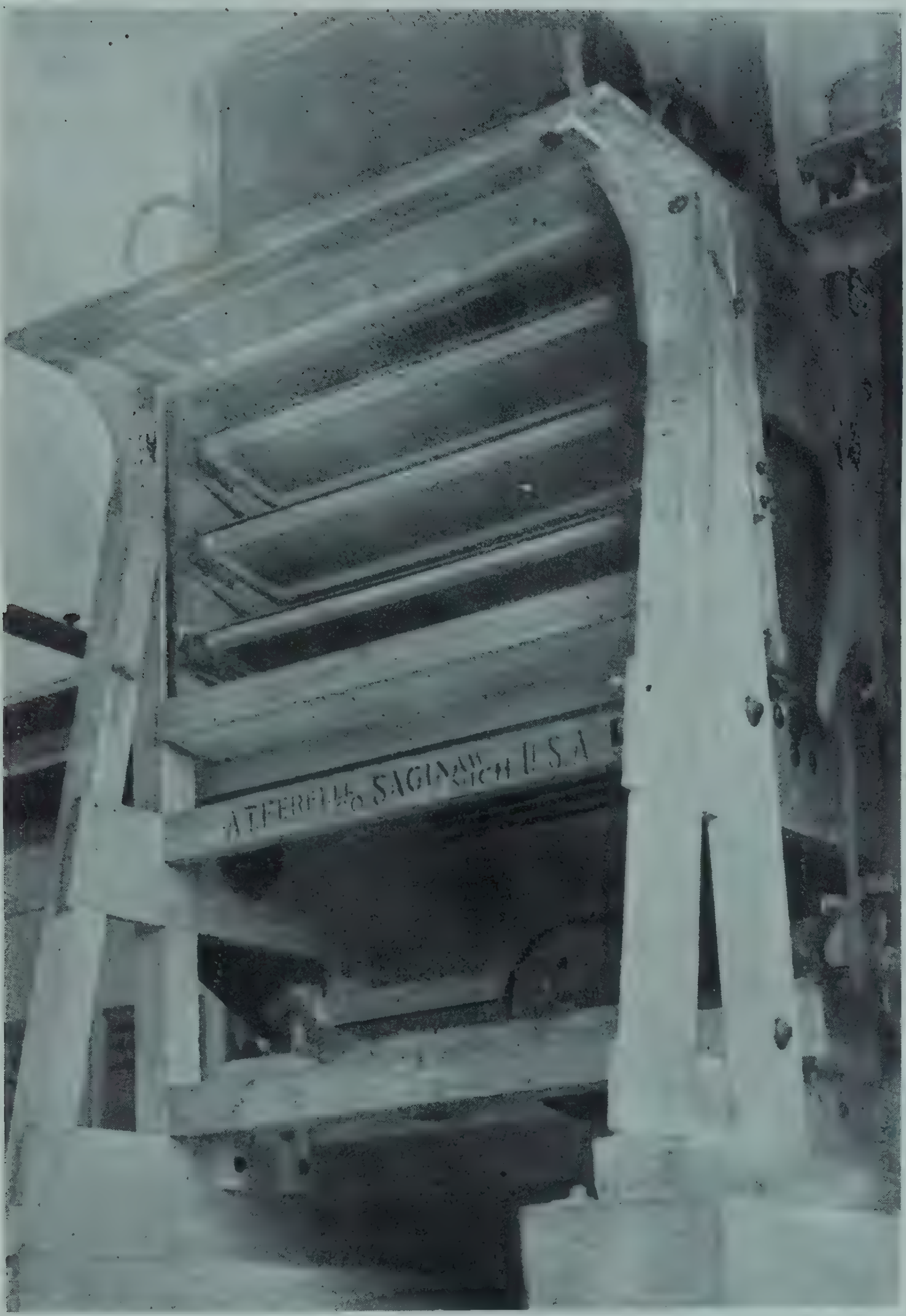
Each expeller usually has its own individual cooker mounted on it for conditioning the flaked meats for extraction. The meats are cooked and dried to a maximum temperature of 240°F. so that the material entering the vertical expeller has a moisture content of 3.0 to 3.5 per cent. The meats, before cooking, are humidified to the extent of 12 to 13 per cent. moisture content. As the meats pass through the expeller, considerable pressure up to 10 to 12 tons per square inch is developed and the pressed cake contains about 4 to 4.5 per cent. oil, thus yielding 10 to 20 pounds of additional oil per ton of seed when compared with hydraulic pressing. The frictional heat developed during pressing is reduced by circulating continuously cooled settled oil over the expeller barrel. This also minimises the colour fixation in the oil.

The oil expressed from the meats, together with the cooling oils, passes on to a continuously discharging oil settling tank. The meal settlings are discharged continuously and returned to the expeller feed. A portion of the settled oil is passed through a heat exchanger and cooled to about 150°F. and circulated over the expeller barrels. The excess settled oil is filtered before passing on to the oil storage. The filter press mud from filtering is also mixed with the expeller feed. The hot expeller cake is cooled before or after grinding, with humidification in a cake or meal cooler and stored in bulk or sacked.

Modern screw presses employed in the United States are high-powered and have a capacity of 25 to 33 tons of cotton seed for 24 hours.

Solvent Extraction. Basically, solvent extraction is a simple process. It merely means mixing an oil bearing material with a suitable solvent. The

PLATE XVII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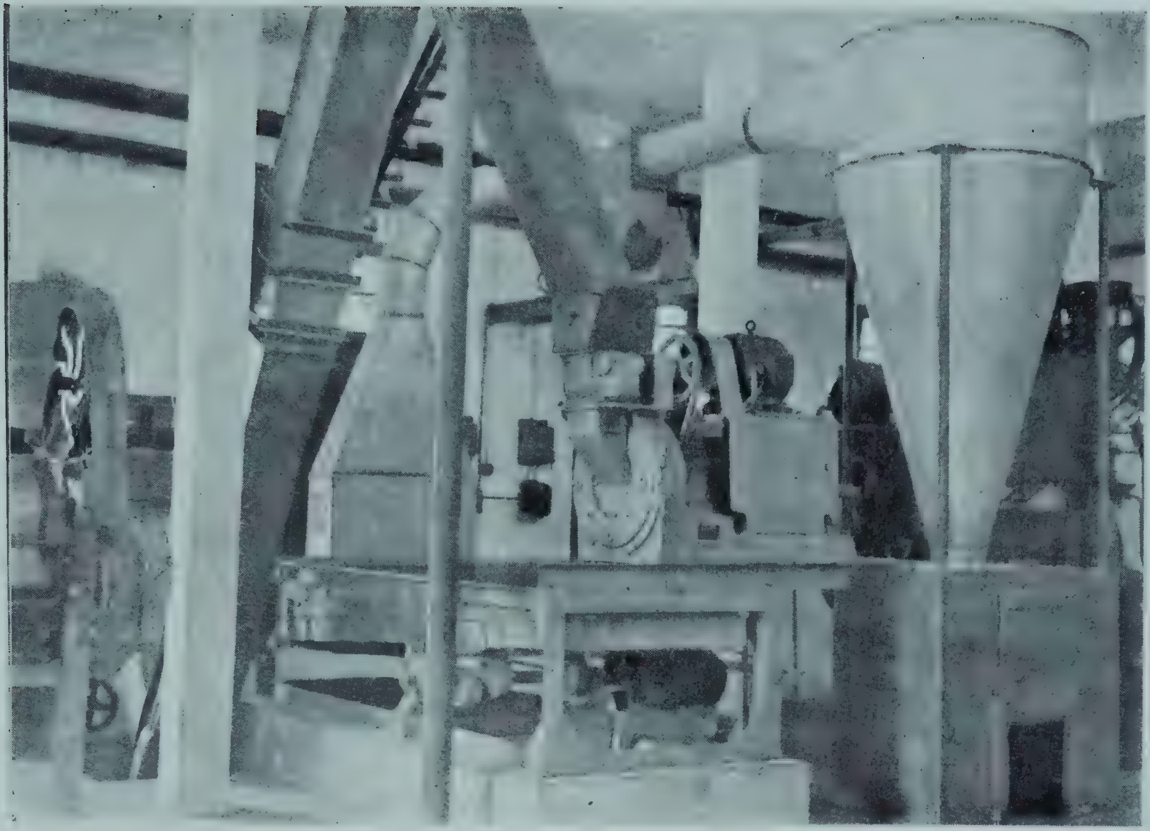
Cotton Seed Cleaning Unit

(By Courtesy, Oil Technological Institute, Anantapur)

a. Typical Modern Delinting Machine
(By Courtesy, Oil Technological Institute, Anantapur)

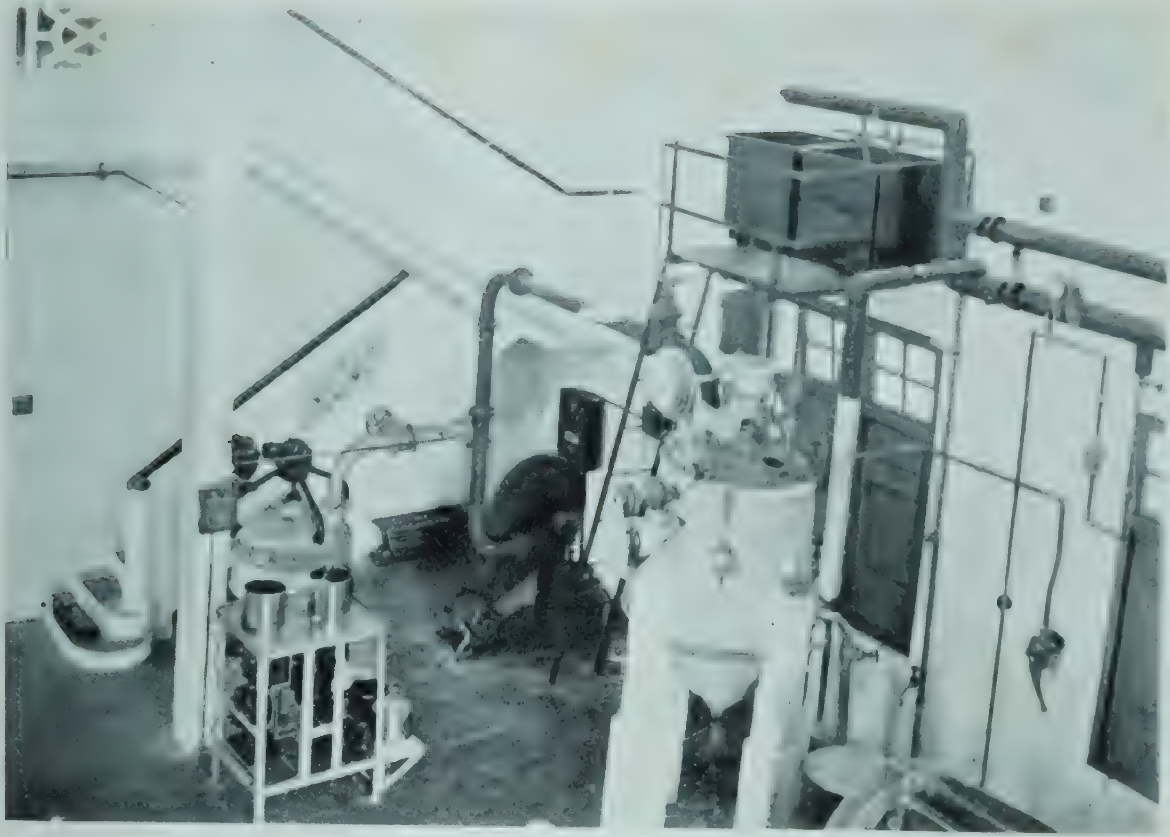
b. Filing Machine for Sharpening Linter Saws
(By Courtesy, Oil Technological Institute, Anantapur)



Typical Modern Dehulling Machine

(By Courtesy, Oil Technological Institute, Anantapur)

PLATE XX



Combined Refining and Bleaching Vessel

(By Courtesy, Oil Technological Institute, Anantapur)

oil is recovered from the miscella (oil solution in the solvent) by removing the solvent by distillation. But, in actual practice, due to the volatile and inflammable nature of the solvent, the solvent extraction plant is much more elaborate and complicated. Such factors as temperature, moisture and flaking must be more closely controlled in solvent extraction than in pressing for a satisfactory extraction. However, the higher recovery of oil in this process more than compensates the higher investment and risk involved in it.

There are several types of solvent extraction equipments for both batch and the continuous processes. The batch process is employed in small capacity plants and is less efficient and involves greater operation costs. The continuous process which is employed advantageously for higher capacity plants involves greater initial cost of equipment and erection but will ultimately be more economical, yielding a higher return.

The principal kinds of continuous extractors used in the cotton seed industry are known as the immersion type and the basket type. In either, proper preparation and conditioning of meats is necessary. This is done by passing the cotton seed meats through the cracking rolls to the conditioner or cooker (usually stack cooker), where desired temperature or moisture content is attained and then to the flaking rolls, where flakes of desired thickness are made. In the cooker, the meats are cooked at a maximum temperature of 174°F. for 20 minutes. The object of this preparation is to break down the structure of the seed so that the solvent has the greatest access to the oil it must remove.

Immersion Type Extraction. The conditioned flakes are carried from flaking rolls to the top of the extractor. The extractor column contains a series of perforated horizontal plates. Rotating scrapers stir the flakes and push them through the perforations. The solvent, hexane for the most part, is pumped in from the bottom of the extractor, moves upwards against the falling flakes and dissolves out the oil. Thus, the fresh solvent comes into contact with the low oil content flakes at the bottom of extractor. The miscella overflows the top of the extractor column and goes through a series of centrifuges, heaters, filters, evaporators and condensers which remove all traces of solvent. The oil, when cooled, is ready for storage or shipment. The reclaimed solvent is returned to storage

The extracted flakes are drawn off from the extractor and elevated above the solvent level, where much of the solvent drains out of them. Final traces of solvent are drawn off in a series of driers, condensed and returned to storage. The solvent-free meal (spent flakes) then goes through the meal toaster, cooler, sifters and grinders to the sacking equipment or storage.

Basket Type Extractor. Steps for the preparation of flakes for the extractor are virtually the same as for the immersion type plant. Conditioned flakes are carried to the filling column on the top of the extractor. This type of extractor has a series of baskets on an endless chain. These baskets have perforations in the bottom for the escape of the solvent and oil. The baskets, filled with conditioned flakes and miscella at the top of the extractor, move down the side. The miscella filters through the flakes and into the basket.

At the bottom, the baskets make the turn and start up the opposite side of the extractor. During this upward trip, fresh solvent is continuously injected near the top of the extractor to remove the final oil. The baskets dump the spent flakes at the top of the extractor and are immediately re-loaded. As in the case of immersion extraction, the spent flakes go through the process of solvent removal, toasting, cooking, moisture adjustment, screening and grinding to the sacking equipment or bulk storage.

In the basket extractor, miscella is drawn off from the bottom of the extractor, the solvent removed, the oil cooled and moved to storage in much the same kind of equipment as that used in the immersion type plants.

In addition to the above two kinds of principal extractors, two other types of extractors have come into prominence recently. These are the De Smet Continuous Extractor and the Filtrex process of extraction.

Pre-Press Solvent Extraction. A new development in the solvent extraction field is the use of screw presses in conjunction with, and ahead of, the solvent unit. Hence the term pre-press. The process is used in either immersion or the basket type system.

In pre-pressing, meats are prepared for extraction in the same manner as described for the screw presses. Presses are speeded up on the same order as the high capacity screw presses, and a greater quantity of material is run through them. The object is to reduce the oil content of the press cake to around 10 to 14 per cent. Oil obtained in the pressing operation is handled in the same way as the oil from the screw press described previously.

The screw press cake is run through a cake breaker or granulator, a conditioner for heat and moisture adjustment, then through the flaking rolls and to the extractor. The pre-press plants cook the meats at a temperature range of 200° to 240 F. for 45 to 60 minutes before extraction. These flakes are tougher and more easily handled than the ones in straight extraction. They move through the extractor in the same way and desolventizing of the products is the same as in straight extraction. Since the meats are cooked in the screw pressing process, it is not necessary to toast the meal. This meal will contain less residual oil than straight extracted meal.

Solvent machinery in all the plants is located in a separate concrete and steel building. Usually commercial hexane is used as the solvent and a solvent loss of two to three gallons per ton of seed processed occurs. The pre-press mills leave one per cent. or less oil in the meal and the straight solvent mills leave 1.5 to 2.5 per cent.

PRESENT CONDITION OF COTTON SEED MILLING INDUSTRY IN INDIA

GENERAL SURVEY

Though India was the second largest cotton seed producing country in the world before partition and the third largest for the year 1954-55, cotton seed crushing industry has not developed to any marked extent in the country. The Indian Cotton Oil Mills, Navsari, was perhaps, the first regular cotton seed crushing mill established in the early thirties of this century. It had rated daily capacity of 60 tons. The Sakseria Oil Mills established in 1937 in Hyderabad, Sind, with a daily rated capacity of 125 tons was, perhaps, the first fully modern plant with entirely American equipment. The cotton seed crushing industry had also developed to some extent in the Punjab before partition. Several other mills had also sprung up subsequently in some other States, notably in Madhya Pradesh.

The progress made in the development of this industry during the past two decades is, on the whole, rather slow. Correct statistics regarding the number and capacity of existing mills, the quantity of seed crushed and oil produced annually are not available. The published estimates are often conflicting. Thus, the Panel on Oils and Soaps Industries set up by the Government of India in 1946 has reported (1947), that 3,00,000 tons or 15 per cent. of the total seed produced in the country was being crushed for oil. According to the information furnished by the Indian Central Oilseeds Committee (1954, 1955, 1956) 45,176 tons and 48,340 tons of seed were crushed, producing 5,582 tons and 5,990 tons of crude oil, respectively, for the years 1952-53 and 1953-54. These correspond to 4.1 per cent. and 3.5 per cent. of the total production of seed for the respective years. According to information furnished in 1956 by the Vanaspati Manufacturer's Association, 8,580 tons and 8,060 tons of cotton seed oil were used in the Vanaspati industry during 1953 and 1954, respectively. These quantities are higher than the reported quantities of crude oil produced during these years. The Oilseeds Crushing Industry Inquiry Committee reported (1956) that during 1954-55, a quantity of 56,687 tons of seed, corresponding to 3.8 per cent. of the total seed produced, was crushed, yielding only 6,934 tons of crude oil. Sixty three mills during 1952-53 and 1953-54, 86 mills during 1954-55 and 45 mills during 1955-56 are stated to be engaged in cotton seed crushing. It is, however, stated that the list of the number of mills working during 1955-56 is not complete. These mills are located mostly in the States of Bombay, Madhya Pradesh and the Punjab and to a lesser extent in Hyderabad, Madhya Bharat and Andhra. From the above information, the yield of oil and the average annual and daily turn-over per mill for the years 1952-55 are given in Table 38. It must, however, be emphasised that the figures are only approximate, as full and correct statistics in this regard are not available.

TABLE 38. NUMBER OF MILLS CRUSHING COTTON SEED, QUANTITY OF SEED CRUSHED, YIELD OF OIL AND AVERAGE TURN-OVER PER MILL DURING YEARS 1952-53 to 1954-55

Year	Seed production (tons)	Seed crushed		Crude oil produced (tons)	Oil yield (per cent.)	Number of mills worked	Average turnover per mill (tons)	
		(tons)	(per cent.)				Annual	Daily*
1952-53	1,096,000	45,176	4·1	5,582	12·4	63	717	3·6
1953-54	1,388,000	48,340	3·5	5,990	12·4	63	767	3·8
1954-55	1,504,000	56,687	3·8	6,934	12·2	86	659	3·3

*.Calculated on the basis of crushing cotton seed for 200 days per year.

The very low percentage of seed crushed, yield of oil and extremely poor turn-over of the mills given in Table 38 pointedly reveal the very backward condition of cotton seed crushing industry in India at present. This will be noted especially when it is realised that in the United States as high as 89 per cent. of the seed produced was crushed during 1952-53 and the average yield of all mills there for the six years (1948-54) was 16.3 per cent., even after making due allowance for the higher oil content of the United States seed.

The total cotton seed crushing capacity of the mills in India is not known. Nor is it known with certainty how many of them are modern units, in respect of their equipment and the processing techniques employed. From the information received from many of the mills and from other sources, it is found that the existing cotton seed processing mills fall mainly under two categories, those that crush the whole cotton seed without giving it any mechanical pre-treatment and those that follow the modern American practice, as described in the previous section. Some of the mills coming under the first category clean the seed in improvised arrangements and a few mills also give a light delinting. Further, some mills falling under this category crush cotton seed directly only for a few months in the season with the existing equipment and crush other oilseeds for the rest of the year. There are said to be about 25 such mills operating in the country. Most of these are located in Madhya Pradesh, the Punjab, Pepsu, Rajasthan and Saurashtra. Other mills falling under this category crush seed for longer periods, limited probably only by finances and storage facilities. These crush mainly *desi* variety seeds without giving the necessary mechanical pre-treatment properly, i.e., either delinting only or dehulling only is done after cleaning the seed. These are mostly located in Madhya Pradesh and the Punjab. It is reported that more than 50 mills falling under the above category were working in the Punjab before partition but are mostly closed down now.

The second category of mills constitute the organised sector of the industry, and process cotton seed employing the modern American methods and equipment for the mechanical pre-treatment of the seed, and extract oil using expellers. There are some eight of these mills in the country operating in Bombay, Madhya Pradesh, Mysore and Andhra Pradesh. These are generally of a much larger individual capacity than the mills falling under the first category and normally work for as long a period in the year as possible. These mills obtain higher yields of oil of better quality and also superior quality cake. Even so, a major portion of the seed is at present processed by crushing the whole seed directly, sometimes even by those mills which are fully equipped for the mechanical pre-treatment.

Crude cotton seed oil produced in India is darker than that produced in the United States and gives higher refining losses than the latter. This can be attributed, partly at least, to the poor processing conditions employed in India. The undecorticated cotton seed cake is of poor quality with low protein and high lint and fibre contents and consequently its feeding value is less than that produced in the United States or by the organised sector of the industry in India. With the exception of a few modern mills, the processing methods employed are not properly controlled in most of the mills. Insufficient or no attention at all is paid to the proper storage of the cotton seed in the gins or oil mills. The valuable cotton linters are not recovered in a good majority of the mills, and the linters produced in others are not cleaned or graded according to their quality. Even the mills equipped for processing by modern methods often resort to cirshing cleaned whole seed, owing to unfavourable market conditions for producing linters and decorticated cotton seed cake.

To sum up, the cotton seed processing industry in India, which is in its infant stage, needs very considerable all round improvements.

FACTORS CONTRIBUTING TO THE PRESENT POOR CONDITIONS OF COTTON SEED MILLING INDUSTRY

A critical review was made by the author in 1952 of the various factors that cotribute to the present poor condition of the industry (Murti, 1952). They still hold good to a large extent. They are the following :

The first and formost factor is the prejudice of the Indian farmer against feeding his cattle with cotton seed cake. He believes that the whole seed is a superior feed. Therefore, the cake which is an important bye-product of the cotton seed milling industry cannot be marketed. This position has somewhat improved recently, partly by the farmer's gradual acceptance of the cake and partly by exporting it. The second important factor is the lack of full knowledge of the modern technique of cotton seed processing and the information on the composition and uses of the various products obtained. Thirdly, unlike most other common edible oils available in India, crude cotton seed oil cannot be used for edible purposes directly, without refining it. This appears to present an impediment in undertaking cotton seed processing to a large extent. So, the cotton seed processing industry has to depend mainly upon export trade for the oil and cake produced. The export policy of the Government of India not being a long-range one, the uncertainty caused thereby is not very conducive to the starting of new mill or utilising the existing oil mills with suitable modifications for processing cotton seed. The fourth is the difficulty in finding ready market for the bye-products in chemical industries which can utilise the cotton seed linters and hulls. The fifth is the quality of the oil, produced by the current practice in India, which is poor, being darker in colour and having high free fatty acid content, involving greater cost and refining loss. The cake produced is also inferior in its nutritive value. Further, the soap stock produced from such oil is also too dark to have ready or full demand from the soap industry. The sixth is the yield of oil which is rather low being on an average 12 to 13 per cent. compared to 16.3 per cent. in the United States. This low yield is partly due to the comparatively less oil content of the Indian cotton seed and partly to the inefficient processing methods and equipment employed in the mills. Lastly, the present non-versatility of the oil mills makes it less economical to process only a single oil seed during its season and keeping the mill practically idle for the rest of the year, as is done in many mills. If, on the other hand, the mill is designed to process cotton seed as well as other oilseeds available in the locality, it will be more economical to run the mill practically throughout the year.

HOW THE INDUSTRY SHOULD BE DEVELOPED IN FUTURE

From the foregoing information on cotton seed, which is the second largest oilseed produced in India, it is obvious that the products derived from cotton seed are important to the national economy. Therefore, it is necessary that processing of cotton seed in the country should be developed on sound and efficient lines, right from the purchase of seed to the marketing of the finished products. To start with, grading of cotton seed, both for purchasing and storing should be enforced. If the seed is graded on the basis of quality and quantity and premia paid to better quality seed and discount made to poor quality seed, it will work out to the advantage of both the seed processor and producer. Next, the seed should be sorted out according to grade at the mills and stored separately under safe conditions, taking necessary precautions to minimise the damage in storing. Poor quality cotton seed should be processed straightaway, admixed in smaller quantities with good quality seed. The seed should be processed by the modern methods of delinting, dehulling, flaking, cooking and extraction so that maximum amount of better quality oil and cake can be produced and the valuable bye-product, linters, is not lost. For this purpose, it would be necessary to modernise the existing mills by putting in additional equipment for giving the mechanical pre-treatment to the seed as described earlier.

The linters should be cleaned and graded suitably for different industries for which they can be used in India or outside. Processing conditions and the quality of products should be controlled by quick laboratory checks. Cotton seed mills should be made flexible to crush other oilseeds so that they keep working throughout the year. Technological laboratories should undertake to work out improved methods of milling and oil refining and obtain technical data in order to help the millers in producing quality products. Engineering workshops and institutes should devise and fabricate the necessary equipment in the country. Meanwhile, facilities to import the necessary equipment, free of import duties and to export the surplus products not consumed in India, should be offered by the Government.

The nutritive value of the oil and the decorticated oil cake should be brought home to the people through practical demonstrations and propaganda by the Government, Food and Agriculture and Animal Husbandry Departments. The public and the farmer would learn to consume the oil and the cake, respectively, in due course by such efforts.

PROCESSING AND UTILISATION OF COTTON SEED OIL

PROCESSING OF COTTON SEED OIL

The removal of the dark colour of cotton seed oil is not so easily attained as in the case of other vegetable oils and is attended by greater refining losses in the process of removing it. The colour of crude cotton seed oil produced in India is, in general, darker than that produced in the United States. Therefore, it is even more difficult to obtain the light colour of the refined oil to the same extent as is done in the United States, for instance. The colour of cotton seed oil is mainly due to the presence in it of gossypol and gossypol like pigments. These are extremely unstable and sensitive to oxidation. The degradation products are difficult to remove, and colour reversion occurs because of them. Hence the removal of colour is a real problem in the case of cotton seed oil. In fact, it is stated that one of the reasons for the decline in the use of cotton seed oil in the Vanaspati industry in India during the last two or three years is due to the difficulty in refining the crude oil to a satisfactory colour, without entailing undue refining losses. Thus, while 4,400 tons, 8,580 tons and 8,060 tons of cotton seed oil were used in the Vanaspati industry during the years 1952, 1953 and 1954, respectively, only 444 tons and 1,159 tons of the oil were consumed in the years 1955 and 1956, respectively.

By refining of cotton seed oil is meant the treatment of the crude oil with the requisite amount of caustic soda solution, varying in its sodium hydroxide content. The caustic combines with the free fatty acids of the crude oil to form soap, extracts the colouring matter by a selective solvent action, coagulates phosphatides and other minor constituents and removes the suspended foreign matter, such as traces of meal and dirt. The above material is thus rendered insoluble in oil and is removed by gravity settling. It is known as soap stock or foots. A successful refining should remove most of the colour and non-fatty matter with the minimum loss of oil and should contain only traces of free fatty acids. The success of all succeeding steps, such as bleaching, hydrogenation and deodorising depends upon the efficiency with which refining has been carried out (Plate XX).

Refining Procedure. Before refining any batch of oil in the plant it is necessary to carry out preliminary test in the laboratory to know the behaviour of the oil towards alkali refining, since practically every batch of the oil produced differs from every other batch in its behaviour in refining. From the laboratory tests, the appropriate strength and excess of the alkali that should be used in the plant can be determined. Normally 16° or 18° Be' lye, with 100 to 200 per cent. excess is found suitable for refining the Indian crude cotton seed oils. The actual refining on the plant is carried out in the following manner (by the batch or kettle process).

Dry Refining: After the kettle is charged with crude oil, the agitator is started at medium speed (20-25 r.p.m.). The speed is then increased to the maximum (35-40 r.p.m.). The requisite quantity of the lye, as determined by the laboratory test, is added to the oil at the room temperature, as rapidly as possible. Agitating at high speed is continued for 15 to 20 minutes to permit the thorough mixing of the caustic solution in the oil. When a slightly granular texture appears on the surface of the oil, the speed of agitation is slowed down slightly and heat is applied through the steam coils, increasing temperature of the oil at a normal rate of about 2°F. per minute, till a maximum temperature of 130° to 140°F. is reached. As the temperature rises, the appearance of the kettle feed changes and a true break takes place. As the break progresses, the agitation should be slowed down progressively. As the size of the soap particles gradually increases, hand samples are withdrawn from the kettle and observed. When soap stock becomes sufficiently soft to melt and run together in the hand sample and when settling is rapid, the operation is complete. In the last phase of the operation, the speed of the agitator should be as low as possible (about 8-10 r.p.m.). When the above condition is reached, the mass is allowed to rest for overnight or at least for eight hours. After settling, the refined oil is withdrawn from the top by swinging suction pipes (swivel pipes). After last traces of oil are skimmed, the foots are run down into foots tanks which are equipped with steam coils. The foots are heated and a further amount of oil is withdrawn. This oil will be darker in colour and is usually added to the next batch of crude oil.

Sometimes, the refined oil is given a washing with 5 or 10 per cent. hot water to remove small quantities of soap held in the refined oil. The latter is sometimes dried under vacuum and sent for storage or immediate processing.

Wet Refining: The above-process is usually termed the dry method of refining. Sometimes, in the case of darker oils, a modification of it, called the wet method of refining, is adopted. According to this, the oil is heated first to about 120°F. and the lye is added. After stirring the oil at the maximum speed for about 20 to 30 minutes, the speed is reduced and the temperature is raised to 140°F. After the break has occurred, stirring is stopped and brine is sprayed over the oil and allowed to settle overnight. After draining the soap stock from the bottom of the kettle, three or four water washes are given to the refined oil to remove all the dissolved soap in the oil.

Re-refining : Re-refining is carried out employing about two to three per cent. of 20° Be' lye usually, or three to five per cent of 16° Be' lye sometimes, in the same way as described above under the dry or the wet method. In the case of very dark oils 1.0 to 1.5 per cent. of 40° Be' lye is added to the oil in the cold and agitated for about 15 to 20 minutes. The soap particles in this case are firm and have little tendency to coagulate and hence the agitation is reduced subsequently and the contents are heated with steam to 130° to 140°F. At this stage, hot water (180°-200°F.) is sprayed over the oil surface for softening the soap particles and the speed is much reduced. When the foots have melted and coagulated, the speed is reduced to the minimum. When the proper break is obtained, stirring is stopped altogether and the mass allowed to settle.

In the course of the refining work carried out at the Oil Technological Institute, Anantapur (Krishna Rao and Murti, 1958a), it has been observed that even though the use of 40° Be' lye generally gives lighter coloured refined oils, it results in much higher re-refining losses. However, the re-refining oils obtained with the use of 20° Be' lye can also be bleached to the same extent as those obtained with the use of 40° Be' lye. Hence it is recommended that for re-refining 20° Be' lye may be used on the weight of the oil.

In addition to the conventional kettle process, another continuous centrifugal process, using caustic soda solution in one step or soda ash and caustic soda solutions in two steps, is employed to an increasing extent commercially. In India, only the batch or kettle process is employed. The advantages of the continuous methods (which are employed extensively in the United States and many other countries) over the batch method are decisive. There will be a net saving of prime crude oil of 1.5 to 3 per cent. over kettle process, i.e., the saving in the loss of neutral oil will be 25 to 40 per cent. of the losses incurred in the kettle process. Generally, the higher the free fatty acids, the greater is the net saving by the continuous proceses which are not so dependent upon the judgment and experience of the refiner, as is the case with the open kettle process. Hence the adoption of the continuous process in India will be benefiicial.

The refining of cotton seed oil in India has not yet attained the same efficiency as in the United States, for instance. The main factor responsible for this state of affairs is the defective method of crushing the whole cotton seed directly, adopted by a large majority of the mills in India, which results in the production of poorer quality oil with darker colour. The time of storage of the oil and the temperature at which it is stored also have a big influence in removing the colour subsequently. Minimum storage period at as low temperatures as possible is advisable. Lastly, many of the millers in preparing 'washed oil' in order to get the required colour, give a light bleach to the oil after the alkali refining. This bleaching seems to fix the residual colour to some extent and complaints have been received by foreign importers of the washed oil that subsequent removal of colour becomes difficult and entails refining losses.

Work Done in India on Refining of Cotton Seed Oil. Investigations on the refining of cotton seed oil are being carried out in some technological laboratories in India, and some useful data has been obtained. The work is being continued at the Regional Research Laboratory, Hyderabad, and the Oil Technological Institute, Anantapur. Bhasin and Aggarwal (1953) reported that a light coloured oil was obtained by double refining (re-refining) the crude cotton seed oil. Narayana Rao and Kuppuswamy (1953) refined and re-refined nine samples of crude cotton seed oil obtained by expressing steamed cotton seed kernals. Harigopal *et al.* (1958) made preliminary studies on the refining of cotton seed oil obtained from different mills, using standard A.O.C.S. methods, and observed that single refining lowers the colour of the oil (½cm. cell) to an average of 8.0 yellow and 1.0 red units and on bleaching, to about 2.0 yellow and 0.4 red units. They also observed that re-refining of the oils can reduce the yellow colour much further and practically removes the red colour. Further work is reported to be under progress on the removal of colour with different strengths of alkali and on the comparative merits of wet and dry methods of refining.

Krishna Rao and Murti (1958a,b) have studied several aspects of cotton seed oil refining on a large number of oils produced in different mills and the pilot plant at the Oil Technological Institute, Anantapur. On storing three different samples of the crude oils for a period of six months, it was found (Krishna Rao, Thirumala Rao and Murti, 1958), that some colour fixation took place which increased with the length of storage. The phosphatide content of 20 different mill samples of freshly crushed cotton seed oils were found to vary from 0.46 to 2.74 per cent. The recovery of phosphatides made from 10 of the above samples (phosphatide contents 1.85 to 2.74 per cent.) ranged from 1.44 to 2.36 per cent. on the weight of crude oil, corresponding to 60 to 87 per cent. recovery, while the recovery from four samples of settled oils varied only from 0.33 to 0.64 per cent. It was also found that by refining, after degumming the crude oil, saving in the refining loss of oil varying from 0.2 to 0.6 per cent. could be effected in six cases and 3.5 per cent. in one other case, in addition to the recovery of the valuable bye-product of commercial lecithin. It should, however, be noted that the combined loss of oil obtained in degumming and re-refining was found to be generally greater than that obtained in refining the corresponding non-degummed oils.

On refining 30 samples of different expeller oils in the laboratory, following the A.O.C.S. methods, it was found that 63 per cent. of the samples gave satisfactory colours by refining once and bleaching to get the lighter colour specified by the Indian Standards Institution. It has also been found that the addition of certain chemicals, both electrolytes and non-electrolytes, such as tetra-sodium pyrosphosphate, salicylic, citric, tartaric oxalic and phosphoric acids in small amounts varying from 0.05 to 0.5 per cent. immediately preceding neutralisation, has resulted in the reduction of refining loss to the extent of 8.0 to 20.5 per cent. of the losses which occurred when the chemicals are not used (Krishna Rao and Murti, 1957). It was also observed that by giving an alkali wash after caustic refining, a further reduction in colour was obtained.

Mathur (1954) reported that the absorption in the colour by active carbon during hydrogenation in the convertor is considerably more than by the usual process of bleaching. He showed that considerable economy can also be effected by this modification. He also observed that in the process of second neutralisation, the addition by soda ash solution after the addition of caustic soda served to effect a comparatively large drop of colour. In one charge, a marked drop from 35Y + 4R to 11Y + 1.4R was obtained.

The average refining loss for American cotton seed oils for the years 1942-46 was 8.44 per cent. By effecting improvements in the methods in the refineries, it has been reduced over the subsequent years to six to seven per cent. for most mills (Fetrow *et al.*, 1956). Based on almost 3,000 samples, average refining loss in 1953-54 was 6.3 per cent. for the 14 co-operative mills. It was 5.8 per cent. for solvent mills, 6 per cent. for hydraulic mills and 7 per cent. for screw pressed mills.

The refining losses of Indian cotton seed oils in the mills are not known but the author understands that they are considerably higher. It is, therefore, considered essential that a more systematic and sustained work should be carried out on the nature of the compounds responsible for the colouring matter and the factors responsible for colour reversion of cotton seed oil.

Bleaching. Bleaching of cotton seed oil is almost invariably carried out after the refining treatment (which effects some reduction of the colour) and prior to hydrogenation and deodorisation. The object of bleaching is to remove colouring materials which are relatively unaffected by refining. Although such substances are unobjectionable from the point of view of edibility, the preference of the consumer is for light-coloured oils. In most cases this preference rests upon the somewhat mistaken impression that colour is a general index of purity and general high quality. Anyhow, since the preference of the consumer cannot be ignored, the production of light-coloured oils is of primary concern of the manufacturers of edible products.

Bleaching of cotton seed oil is accomplished by treating the oil at more or less elevated temperatures with small percentages of finely divided activated bleaching clays, usually adding activated carbon as an adjunct to clay. The bleaching operation is carried out in an open tank or in a vacuum bleacher under a vacuum of 27 to 28 inches. The bleachers are also equipped with steam coils and mechanical agitators. The oil is dried usually under vacuum before adding bleaching (activated) earth. The oil is heated to 220° to 230°F. in open vessels or to about 212°F. or slightly higher in closed vessels under strong agitation and varying amounts, two to four per cent., of bleaching clay are added. Activated carbon, approximately 10 per cent. on the weight of the clay or activated earth is also added to improve the bleaching. After heating under agitation for 25 to 45 minutes, the mixture of oil and clay is pumped through a filter press and recirculated to the bleacher till a clear oil with maximum reduction in colour is obtained, when it is collected separately.

The oil absorbed by the bleaching clay and carbon is recovered partially in some cases from the filter press cake by steaming or boiling with sodium carbonate solution or by extraction with organic solvents, but the recovered oil is of poor quality.

Winterisation. In the United States and other Western countries large quantities of cotton seed oil are used as salad and cooking oils. As refined cotton seed oil solidifies at temperatures not much below 32°F. without the removal of its saturated glycerides, a considerable portion of the more saturated glycerides must be removed from the oil, so that it may remain bright and unsolidified at low temperatures such as those likely to be encountered in the domestic ice-box and in winter months. The process of removal of the saturated glycerides is known as winterisation.

In order to increase the yields of processed salad oil, refiners producing both winter oil and shortening usually subject the unwinterised oil to a preliminary settling in storage tanks in the yards at out-door temperatures during fall and early winter, when the temperatures are not too low. This results in crystallisation and settling down of the more saturated glycerides or stearine. The oil drawn from the upper layers of the storage tank is taken to the winter oil plant, while oil from the lower layers is taken for shortening manufacture. This procedure has the double advantage of getting higher yields from the winter oil plant and obtaining the less required drop in iodine value in converters in the hydrogenation plant.

The winterising tanks are fixed in a well insulated room equipped with refrigeration, with the cooling coils either fixed in the tanks or outside in the room. The oil to be winterised is first given a light cleaning bleach and dried, before the winterising tanks are filled with it, at a temperature of 90° to 95°F. The temperatures are so adjusted that a charge of oil is brought down to 38° to 40°F. at a uniform rate in about three days. As the end of the chilling period approaches, the temperature is watched very carefully. As the more saturated glycerides crystallise from the oil, the release of the latent heat causes the temperature of the whole mass to raise by two or three degrees. When this heat is absorbed, the temperature begins to fall again. The proper time for filtration of the mass of oil is that point where the temperature of the tank begins to fall below the lowest temperature attained immediately preceding the above-mentioned temperature rise.

The mixture of oil and stearine is then forced to the press, kept in an adjoining room and maintained at a temperature of 36° to 38°F. The pressure on the press is maintained constant and when oil ceases to flow through the cocks, the press is blown with cold air to remove the oil retained in the press. The winterised oil and the solid stearine in the press are collected separately. The winterised oil, which passes the standard cold test (the oil should remain clear and bright at 32°F. under specified conditions for at least 5½ hours), is then deodorised and packed.

Hydrogenation. Under this section, only the aspects relevant to the hydrogenation of cotton seed oil will be mentioned as the information on hydrogenation of vegetable oils, in general, is well-known.

Cotton seed oil is widely used in the United States and other Western countries in the manufacture of shortening for commercial and household use, for which purpose it is necessary to change the oil from liquid state to a plastic solid form at room temperature. This is carried out by the process of hydrogenation to varying degrees, depending whether an all-hydrogenated or a compound type of shortening is desired to be produced. In the former case, the entire mass of oil is hardened to a given consistency, while in the latter case a part of the oil is hardened almost completely to 140°F. stearine and blending this with unhardened oil to obtain the desired degree of plasticity. In India, where cotton seed oil is used in the production of Vanaspati, it is mixed in minor proportions with groundnut oil and the entire oil mixture is hydrogenated to the desired degree.

Hydrogenation of cotton seed oil is ordinarily carried out in a convertor, capable of withstanding pressures up to 150 lb. by the treatment of the oil with hydrogen under moderate pressures ranging from 10 to 50 lb. in the presence of a catalyst; usually finely divided nickel supported on Kieselguhr and suspended in the oil. The working temperatures generally used are 150° to 200°C. The progress of hydrogenation is usually followed by measuring the drop in the refractive index of the oil in the convertor. The refractive index is directly related to the iodine value of the oil. Cotton seed oil is usually hydrogenated till its iodine value is reduced to 62-66. When the desired reading of the refractive index is obtained, the flow of hydrogen is cut off and the charge in the convertor is cooled to temperatures suitable for filtering out the catalyst. The clear oil is accumulated in storage tanks for further processing. During the process of hydrogenation in the convertor, the colour of cotton seed oil becomes lighter. For the production of fully hardened cotton seed oil, it is hydrogenated till its melting point is raised to about 140°F. The iodine value is reduced to 15 units or less.

The characteristics and composition of the final hydrogenated cotton seed oil product, such as minimum melting point, cloud point, congeal point, etc., and the iso-oleic acids content are controlled by a number of factors in the course of the hydrogenation. These are the type and concentration of catalyst used, the pressure, agitation and temperature of the reaction. Some catalysts are extremely active in the sense that they promote exceedingly rapid absorption of hydrogen but are relatively non-selective, while others may be more selective but much less active. Both the selectivity and the activity of the catalyst is reduced through re-use. Further, some of the more selective catalysts are more susceptible to catalyst poison and cannot be re-used frequently.

The term selective hydrogenation is used in two different senses. According to one sense, it refers to the preferential reaction between hydrogen, of the higher unsaturated molecules, such as linolenic or linoleic glycerides, and the less unsaturated molecules, such as oleic glycerides. According to the second sense, it refers to the iodine value-congeal point relationship in the hydrogenated oil. It is in the second sense that the term selective hydrogenation is used here. It is also sometimes stated as the condition of formation of oleic glycerides with a minimum of the high melting iso-oleic glycerides.

It has been found that the temperature at which the hydrogenation is carried out has an effect on selectivity. Generally, hydrogenation is more selective at lower temperatures than at a higher temperature when the formation of greater quantities of iso-oleic acids takes place. Increase in the pressure and agitation decreases the selectivity. Increase in the concentration of a given catalyst makes the reaction more selective.

The staying quality or resistance to oxidative rancidity of selectively hydrogenated fat is greater than the one containing higher percentages of iso-oleic acids glycerides with unhydrogenated linoleic acid. A selectively hardened cotton seed product will melt slowly and remain plastic for a long time. On the other hand, a non-selectively hardened stock containing high percentages of iso-oleic acid, will show a sharper melting point. For making shortenings, the former property is preferred while for the manufacture of margarine the latter property, which gives a more pleasant sensation in the mouth than does a slowly melting product and which is characteristic of butter-fat, is preferred.

Sometimes due to the increased F.F.A. of the oil in the convertor or the colour of the hardened oil not being light enough, it is refined or bleached again after hydrogenation and prior to deodorisation. In order to produce bland oils of commerce, both winter oils and shortenings must be deodorised.

Deodorisation. Deodorisation of cotton seed oil is done by subjecting it to the action of superheated steam at high temperatures ranging from 375° to 425°F., under a very high vacuum of 5 to 10 millimetres. Winterised oil is usually deodorised at somewhat lower temperatures than compound or all-hydrogenated stock.

Details relating to the deodoriser and the process are too well-known to be stated here. Under the above-mentioned conditions of heating the oil, volatile odoriferous materials and traces of free fatty acids in the oil are distilled off from the stock and carried away with the steam. In the modern process, the heating of the oil is usually done by passing Dowtherm (a mixture of diphenyl oxides and diphenyl which boils at 500°F. at atmospheric pressure) vapours or high pressure steam through heating coils inside the deodoriser. The blowing steam is superheated to 500° to 600°F. at a pressure of 10 to 15 lb. in a superheater which is gas or oil-fired. Deodorisation is complete after four to six hours of blowing, depending upon vacuum and other conditions. The winterised oil is usually deodorised for a somewhat shorter period. The finished oil is cooled to 120° to 130°F. before it is exposed to the atmosphere, since rapid oxidation will occur at the temperature of deodorisation. Inert gases are passed through the lines to prevent air leaks into the system, thereby preventing oxidation of the oil. The whole cycle requires seven to nine hours from charging of the deodoriser to pumping out the finished stock.

During deodorisation, especially at a high vacuum, some free fatty acids distil out of the stock, and the colour of the cotton seed oil is further decreased. The colour drop is probably due to bleaching under heat which is characteristic of cotton seed oil. A winter oil may decrease in colour several full Lovibond red units, while an all-hydrogenated product will drop only 0.1 to 0.2 units.

Continuous processes both for hydrogenation and deodorisation have been developed and practised in the bigger and more progressive plants. Continuous units have a greater capacity and lower processing costs.

Finishing Treatment. Immediately after deodorisation, winter oil is packed and marketed. But in the case of shortening or Vanaspati, despite its increased melting point, it is unsuitable for commercial use. It is further processed before it is put into the final packing, as the finished shortening or Vanaspati from the deodoriser, on cooling to room temperature, will form a mixture of liquid oil and coarse grains of solid fat, which would be obviously unsuitable for use either in the kitchen or in the bakery.

It is, therefore, put through a final process known as 'finishing'. The finishing process essentially consists of rapidly chilling the hardened cotton seed oil to a point below its temperature of solidification, allowing the supercooled liquid to crystallise and kneading it. Air is usually incorporated in the fat during chilling in order to improve the appearance and plasticity of the finished product, except where non-plastic product is desired.

SOAP STOCK

Soap stock is derived from the alkali neutralisation of fatty acids of crude oil. It consists mainly of soap, entrained neutral oil, non-fatty material and water. Soap stock forms on the fatty acid basis about 6.5 per cent. of the total crude oil refined in the United States. From the information gathered from some plants, it would appear that the soap stock would form 10 per cent. or higher of the crude oil in India, when properly refined. The composition of soap stock derived from kettle refining will be approximately, moisture 45 to 50 per cent., neutral oil 18 to 25 per cent., fatty acids from soap 20 to 25 per cent. and the rest non-fatty matter and sodium oxide in combination. Soap stock is evaluated on its total fatty acids which will be about 40 to 50 per cent. in the foots produced in continuous refining.

In India, a portion of soap stock is used in low grade soaps and the balance rejected, while in the United States a major portion of it is used in the manufacture of soap and the balance is processed in distillation plants for recovery of fatty acids and pitch. In the United States the soap stock is usually converted into boiled down soap stock, settled soap stock or acidulated soap stock before disposing it off, as this treatment will reduce freight charges and fetch better prices on fatty acid basis. If this preliminary treatment, which is simple and which will not require any costly equipment, is given by the cotton seed oil refiners in India, they will be able to dispose of the soap stock to greater extent at better prices.

For the manufacture of fatty acids, the soap stock is acidulated and treated for splitting the neutral oil either by the Twitchell or the Autoclave method and distilled by improved and continuous methods of fatty acid distillation. Cotton seed fatty acids are used to the largest extent in soap industry for quality soaps. The next largest use of them is as an ingredient in rubber compounding. Other uses are in the manufacture of resins and as chemical intermediates, such as long chain alkyl amines, amides, esters, alcohols and metallic salts, which have diverse applications as wetting and detergent agents, emulsifiers, modifying agents in plastics and resins, etc. The residual pitch obtained in cotton seed fatty acid distillation is a black material having good water proofing properties. It is used in special paints and varnishes, asphalt tiles, roofing material and electrical wiring insulation requiring high resistance to moisture.

Achaya *et al.* (1955) investigated the possibilities of recovering fatty acids from the Indian cotton seed foots by the urea-adduct method, after saponification and acidification and reported that 82 per cent., of light-coloured fatty acids could be recovered from the dark cotton seed foots derived from alkali refining of cotton seed oil. No other work seems to have been done on this subject in India.

UTILIZATION OF COTTON SEED OIL

Almost the entire production of cotton seed oil is used for edible products. Less than one per cent. of the cotton seed oil is utilised for non-edible products in the United States. Because of the suitable fatty acid composition, cotton seed oil is especially desirable for edible purposes. There is little danger of flavour reversion, since the oil contains no fatty acids. Hence, the oil commands a leading position in the edible field. In the United States and other Western countries, it is used in edible products, such as shortenings, margarine, cooking and salad oils and confectioner's fats. Cotton seed oil is not sufficiently unsaturated to be of value as a drying oil in the paint and protective coating industry. It is not as satisfactory a material for soap manufacture as the other fats, such as tallow, grease, coconut oils, palm and palm kernel oils and other nut oils, some of which are cheaper than cotton seed oil. The relatively high price of cotton seed oil in the United States is probably an important factor against its general use in other industries where its application may otherwise be acceptable. In India, it is used mainly in Vanaspati manufacture and occasionally as 'wash oil' in soap manufacture. The surplus production is mostly exported.

The principal uses of cotton seed oil in non-edible products, which are very much limited in quantities, are in soap, lubricants, sulphonated oils, pharmaceuticals, protective coatings, rubber and as a vehicle for nickel-bearing catalyst. It is used to a lesser extent in the manufacture of toilet articles, leather, textiles, printing ink, polishes and synthetic plastics and resins. Cotton seed oil is not known to be used for any of the above products in India. There is scope for developing the utilisation of cotton seed oil in India in some of the above industries.

Composition of Cotton Seed Oil. Cotton seed oil is classified as a semi-drying oil on account of its high linoleic acid content. The iodine value of cotton seed oil varies from 93 to 115, saponification value from 186 to 201, titre from 30 to 37 and specific gravity from 0.903 to 0.927 at 25°/25°C. It is readily detected in the presence of other oils even in small amounts by the well-known Halphen colour reaction. However, this reaction is destroyed by hydrogenation. The oil contains 0.6 to 2·0 per cent. of unsaponifiable matter, containing mostly sterols, 1.4 to 1.8 per cent. of phospholipids, 0.04 to 0.8 per cent. of gossypol pigments (Desikan, Rao and Murti, 1957) and the rest tri-glycerides. Cotton seed oil also contains 0.10 to 0.14 per cent. of tocopherol (vitamin E). According to Hilditch and Maddison (1940), who made the most complete analysis of the fatty acids of cotton seed oil of iodine value 105, the fatty acid composition of cotton seed oil is myristic 1.4 per cent., palmitic 23.4 per cent., stearic 1.1 per cent., arachidic 1.3 per cent., oleic 22.9 per cent. and linoleic 47.8 per cent. Jamieson and Baughman (1943) after an examination of 41 commercial samples of crude oils collected during 1919-20 season from mills in nine southern States, found that the characteristics of the oils from widely different sections of cotton seed belt, did not vary much, nor did the proportion of the saturated acids. The composition of American oils usually falls within the following limits: saturated acids 23 to 28 per cent., oleic acid 22 to 28 per cent., and linoleic acid 44 to 53 per cent. (Bailey, 1948j).

Regarding the analysis and composition of the Indian cotton seed oil, Hilditch and his co-workers (1949) studied the composition of three samples of Indian cotton seed oil and found that the palmitic acid content varied from 19.6 to 23.4 per cent., stearic acid 1.1 to 2.7 per cent., oleic acid 22.9 to 29.6

per cent. and linoleic acid 45.3 to 50.4 per cent. The iodine values varied from 103.4 to 106.4 and saponification equivalents from 286.4 to 289.3. According to their work, the saturated/unsaturated fatty acid ratio of Indian oils was 21.2-24.5 to 70.7-75.0. The corresponding ratio of five American oils studied by them was 22.2-27.0 to 73.0-76.7. Kane *et al.* (1953) reported the composition of two samples of Indian oil deduced from the iodine and thiocyonogen values and saturated fatty acids. They found in the two samples: saturated fatty acids to be 20.4 per cent. and 20.1 per cent. by weight; 45.2 per cent. and 37.9 per cent. linoleins; 32.2 per cent. and 42.1 per cent. oleins; and 24.6 per cent. and 20.0 per cent. saturated glycerides.

Achaya, Harwalkar and Saletore (1953) analysed four oils by the ester fractionation technique and concluded that two of them contained saturated acids, mainly palmitic 21 to 23 per cent., oleic acid 36 per cent. and linoleic acid 42 per cent., in the other two the oleic and linoleic figures were reversed. The saturated/unsaturated fatty acid ratio of these four oils was reported to be 21-23 (palmitic acid only) to 78. From the analysis of 34 samples of *desi* and American variety crude oils at the Oil Technological Institute, Anantapur, (Desikan and Murti, 1953) the iodine values varied from 91 to 111 and saponification values from 186 to 201. The specific gravities of 18 crude oils obtained from different *desi* and American variety seed in the pilot plant varied from 0.903 to 0.927 at 25°/25°C., giving an average value of 0.917.

Nutritional Aspects of Cotton Seed Oil. Fats serve many functions in human and animal nutrition. Of all food stuffs, fats possess the highest caloric value and must be considered the most concentrated food material from this standpoint. Fats serve as the only source of unsaturated or essential fatty acids (linoleic, linolenic and arachidonic acids) required for the development of animal tissues. These essential fatty acids cannot be synthesised by the animal body to any appreciable extent. They are of special importance as carriers of the fat-soluble vitamins. They are necessary in making diets palatable. Low-fat diets are usually unappetising and their use is often associated with voluntary reduction in caloric intake. Linoleic and arachidonic acids were found to be essential oils of highest activity, while linolenic acid has a somewhat lower potency. Oleic acid is found to be inactive. The effectiveness of the natural fats in preventing fat deficiency diseases must be in proportion to their content of these essential fatty acids. Seed oils are excellent sources of these essential fatty acids while, in general, animal fats are poor sources of these necessary dietary components. Common edible vegetable oils, which have a high proportion of these active essential fatty acids, are cotton seed, corn, sesamum, soyabean, safflower and sunflower and to a lesser but appreciable extent groundnut, rapeseed, olive and almond. Cotton seed oil contains linoleic acid in a proportion of 40 to 50 per cent. of the total fatty acids in it. It has already been stated earlier that cotton seed oil contains vitamin E to a high degree and effective pro-vitamin A in the form of ∝ -carotene and some vitamin B complex.

The nutritive value of a fat will be in proportion to its digestibility. The coefficient of digestibility is the usual index for expressing the degree of absorption. By this term is meant the percentage of the ingested food stuff, which is absorbed. Coefficients of digestibility of different common vegetable fats and oils fed to man are given in Table 39 (Bailey, 1948q). For comparison, the coefficient of digestibility of butter fat and some partially hydrogenated fats (to below 40°C. melting point) are included.

TABLE 39. AVERAGE COEFFICIENTS OF DIGESTIBILITY OF DIFFERENT VEGETABLE FATS AND OILS FED TO MAN

Fat or oil	Number of experiments	Coefficient of digestibility	Coefficient of digestibility of some high m. pt. and hydrogenated fats fed to man
Cocoa butter	11	94·9	—
Coconut	12	97·9, 88·7	—
Corn	7	96·9	94·7 (33°C.)
Cotton seed	12	97·6, 96·9	96·8 (35°C.)
Groundnut	5	98·3	98·1 (37°C.)
Olive	10	97·8	—
Rapeseed	4	98·8	—
Sesame	5	98·0	—
Soyabean	7	97·5, 93·7	—
Butter	8	97·0, 88·9	—

Numerous investigators have reported that higher melting fats are less completely absorbed, in contrast to the practically complete digestibility of animal and vegetable fats where the melting points are under 50°C. (Bailey, 1948q).

There is no single animal fat or vegetable fat which is superior in all respects. With a few exceptions, practically all fats are equally good as sources of calories since they are digested to an extent of 95 per cent. or more, with the exception of fats with a relatively high melting point such as mutton tallow, oleo-stearine and very completely hydrogenated fats. A limited number of animal fats, such as butter, egg yolk and liver fat are good sources of vitamin A. Palm oil is an excellent source of vitamin A. Vitamin D is largely absent both from animal and vegetable oils with the exception of coconut oil. The more concentrated source is the fish liver oils. Vitamin E or ∝—tocopherol is widely distributed in seed oils where it is concentrated in the germ. The best natural sources are wheat germ, soyabean and cotton seed oils, as well as a large number of other vegetable oils. For this reason, they have the added advantage of greater stability due to the anti-oxidant activity of the tocopherols.

Although hydrogenation largely effects the conversion of linoleic acid to oleic acid, analyses indicate that all hydrogenated fats melting in the usual range of Vanaspati, margarine, and shortenings (approximately 35° to 40°C.) may still contain 10 per cent. or more of linoleic or higher unsaturated acids (Bailey, 1948r). The important nutritive qualities which are attributable to vegetable oils are largely retained and in some cases augmented by partial hydrogenation of the oils. Growth, pregnancy and lactation proceed normally when hydrogenated fats melting below 50°C., make up practically the entire fat of the diet.

Thus cotton seed oil stands among the best vegetable oils in its nutritive value.

UTILISATION OF BY-PRODUCTS OF COTTON SEED MILLING INDUSTRY

YIELDS OF PRODUCTS

The important cotton seed products are oil (meal or cake), hulls and linters. Since the industry, as a whole, is not yet properly organised in India, the amounts of the various products obtained in processing cotton seed vary widely and no data is available regarding the average quantities of these products obtained from one ton of the seed. From information obtained from many mills, it is gathered that the yield of oil varies from 10 to 15 per cent. depending upon the variety of seed and the method of processing employed; and the yield of cake from 40 to 80 per cent. depending upon the method of crushing. The yield of linters (where delinting is done) varies from four to six per cent. from American type seed, no recovery of linters being usually made from *desi* seed. The recovery of hulls varies from 26 to 27 per cent. from American type seed and 30 to 32 per cent. from *desi* seed. The yields of these products obtained from 18 runs, each on two tons of cotton seed of both *desi* and American type seeds, made on the pilot plant at the Oil Technological Institute, Anantapur (Desikan and Murti, 1959), is given in Table 40. For comparison, the corresponding yields in the industry in the United States are included in the table.

TABLE 40. PILOT PLANT DATA FROM EIGHTEEN RUNS ON SEVEN DESI AND FIVE AMERICAN TYPE COTTON SEEDS OBTAINED AT THE OIL TECHNOLOGICAL INSTITUTE, ANANTAPUR

Product	Desi type		American type		U.S.A. seed
	Yield per cent.		Yield per cent.		Yield per cent.
	Limits	Average	Limits	Average	
Oil	9·7–12·5	11·1	10·1–14·6	12·3	15·2–16·2
Decorticated cake	38·2–50·6	42·3	39·2–41·8	40·4	44·3–46·4
Undecorticated cake	79·3–80·6	80·1	79·6–84·9	82·3	—
Linters	0·7– 4·0	2·3	4·0– 9·3	6·6	7·2– 9·5
Hull (net yields)	28·0–41·9	36·9	28·2–37·8	32·2	23·1–25·9
Processing losses	2·6– 9·3	6·0	3·5– 6·8	5·5	5·2– 6·9

From a value basis in the United States, roughly the oil makes up about 50 per cent., the cake about 30 per cent., the linters about 13 per cent., and the hulls about three per cent. of the total value of the products. Similar average values for the yields for these products are not available in India. At the present time, crude oil is not purchased as such but only as washed oil. The decorticated cake fetches a higher price both internally and in export trade than the undecorticated cake. The linters are consumed virtually in one or two rayon manufacturing concerns in the country, which are likely to dictate the price and other terms. The balance is exported.

COTTON SEED CAKE

Composition. In India, undecorticated cake is at present produced in larger quantities than the decorticated cake. The composition of the two varieties differs widely. Lander and Dharmani (1930) gave the composition of the undecorticated cake as, moisture 7.48 per cent., fat 8.47 per cent., fibre 22.3 per cent., ash 6.01 per cent., protein 21.13 per cent. and nitrogen-free extract 34.6 per cent. According to Athawale (1944), undecorticated cake contains, moisture 13.75 per cent., protein 24.6 per cent., fat 6.56 per cent., carbohydrates (by difference) 29.3 per cent., crude fibre 21.2 per cent. and ash 4.6 per cent. The corresponding figures obtained by him for decorticated cotton seed cake were, moisture 10.4 per cent., protein 42.37 per cent., fat 7.1 per cent., carbohydrates 25.8 per cent., crude fibre 7.1 per cent. and ash 7.0 per cent. According to the analysis of 14 decorticated cotton seed cakes made at the Oil Technological Institute, Anantapur (Desikan and Murti, 1959), the moisture content varied from 4.1 to 9.3 per cent., oil content from 7.2 to 10.3 per cent., protein content from 29.2 to 44.0 per cent., free gossypol on moisture-free basis nil to 0.061 per cent. and ash content from 7.1 to 7.6 per cent. The composition of four undecorticated cakes was found as, moistue 3.7 to 5.4 per cent., oil content 5.4 to 6.6 per cent., protein 22.2 to 23.9 per cent., free gossypol 0.028 to 0.06 per cent. and ash 4.5 to 6.7 per cent. The composition of American decorticated cotton seed cake as given by Jamieson (1943) is, moisture 7 to 9 per cent., oil 6.5 to 7 per cent., protein 32 to 42 per cent., carbohydrates 28 to 33 per cent., crude fibre 10 to 15 per cent. and ash 4.8 to 6 per cent. According to Cox (1949), one short ton of cotton seed cake contains about four pounds of available phosphoric acid, 138 pounds of nitrogen and 36 pounds of potash. A typical expeller cake produced in the United States contains, moisture 2.75 per cent., oil 4.04 per cent. and protein 43.25 per cent. (Bailey, 1948o). The results from analysis of cotton seed cake produced in the oil mills (hydraulic and screw pressed) for the five-year period of 1942-46 gave the average values of, moisture 7.4 per cent., oil 5.4 per cent. and protein 40.5 per cent. (Bailey, 1948s).

NUTRITIVE VALUE OF COTTON SEED CAKE AS ANIMAL FEED

In all advanced countries, cotton seed cake (meal)has been highly valued as a protein concentrate for livestock for many years. Although the cake contains other substances of nutritional value, such as fat and vitamins, its commercial value is due primarily to its protein content. Extensive studies were made on the nutritive value of the mixed proteins of cotton seed both by the use of nitrogen balance tests and practical feed tests, all of which have led to the conclusion that the proteins of cotton seed are of high nutritive value. From these studies, it was also found that the proteins of cotton seed were equal to the proteins of groundnut cake and superior to the proteins of sesamum cake, copra cake and alfalfa meal for the growth of rats (Smuts, 1938).

The values for the digestibility of proteins of commercial cotton seed cake vary considerably, but it was shown that such variations were due to the variations, such as temperature, time and moisture content used in the manufacturing procedure. Subjecting the cotton seed cake to high temperatures in the processing lowers the digestibility of the cake. Autoclaving the meal or heating the cotton seed with steam under pressure further decreases the overall nutritive value of the proteins.

In the solvent extraction method for the processing of cotton seed, the heat treatment given to the meal can be worked out in such a manner that the proteins in the meal will be left in a more digestible from.

Vitamins and Mineral Content of Cotton Seed Cake. The cotton seed cake is a good source of vitamin B. The removal of oil, by the milling of cotton seed, concentrates the water soluble vitamins in the protein cake, so that the cotton seed cake is richer in these vitamins than the whole seed or even the hulled kernels. The cotton seed cake contains very little of either vitamins A or D. The average values for the content of vitamins and some of the minerals of cotton seed cake are given in Table 41.

TABLE 41. VITAMIN AND MINERAL CONTENTS OF COTTON SEED CAKE

Vitamin	Content mg. per lb.	Mineral	Content gm. per lb.
Riboflavin	4·08	Calcium	0·86
Pantothenic acid	6·35	Phosphorus	5·04
Niacin	20·40	Sodium	0·18
Thiamin	6·13	Pottassium	6·63

As compared to other vegetable protein concentrates of grains, the cotton seed meal is relatively high in phosphorus content.

Gossypol in Cotton Seed Cake. Although cattle and sheep can consume large quantities of raw cotton seed continuously for a long period of time without any apparent ill effect, rabbits, guinea pigs, and swine will die within a short time if they eat very much of it. It was established that this was due to the presence of the toxic material, gossypol, in the seed. During the processing of cotton seed, in the hydraulic or expeller procedure, the cooking or moist heat treatment causes changes to take place in gossypol, which gets inactivated. The amount of free or unchanged gossypol in commercial cotton seed meal, while relatively small in comparison with raw cotton seed, shows considerable variation from sample to sample. The free gossypol content of 44 samples of expeller cotton seed cake produced at the Oil Technological Institute, Anantapur, and four expeller cake samples drawn from mills is found to vary from nil to 0.061 per cent. (Desikan, Rao and Murti, 1957), as compared to that in mechanically processed cake in the United States which varies from 0.028 to 0.084 per cent. The gossypol content of the meal obtained in the solvent extraction process will be higher, as it is not subject to such high heat treatment as in the mechanical pressing methods but this is reduced in the process of toasting given in the cake.

It is shown that any commercial cotton seed cake, as made by the present methods, can be safely fed to hogs provided the amount is limited to nine per cent. of the total ration. Although cotton seed meal is a good source of protein for poultry rations, it is not recommended for laying hens, if the eggs are to be kept in cold storage, as under cold storage, a discoloration begins to develop, particularly in the yolks, which soon makes the eggs unsaleable.

When green pasture constitutes the chief food for dairy cattle, the staying quality of the butter is relatively poor and its melting point is low, making it difficult to handle in warm climates. It was shown (Eccles and Palmer, 1916) that by supplementing green pasture with cotton seed cake, the quality of the butter will improve and that it will stand up better to summer temperatures. The extent of the changes in the physical and chemical properties in butter is dependent not only on the amount of cotton seed cake fed, but also on several other factors, including the oil content of the cake and the nature of other constituents of the ration. It appears that the hardening of butter when dairy cattle is fed with cotton seed cake is due to the selective utilisation of the saturated fatty acids of the cotton seed oil in the cake during the process of milk formation (Bailey, 1948t).

Use of Cotton Seed Cake in Rations for Livestock and Poultry. The value of protein in the dairy ration of animals had been long recognised. In addition to supplying protein, the cotton seed cake is a source of phosphorus and fat in the ration. It is used in dairy ration quite extensively over extended periods. It can safely make up 33 per cent. of the grain ration, both for dairy cows and calves. For dairy cows, the cotton seed cake furnished the most important and cheapest source of protein and sometimes of the total feeding value of any concentrate. It was reported that by feeding dairy cows with cotton seed cake, the yield of milk corrected for four per cent. fat increased than when fed with the normal ration.

Cotton seed cake and meal are standard protein supplements for the feeding of sheep, being extensively used for winter maintenance of range and farm flocks. As a feed for hogs, cotton seed meal is richer in certain minor nutritional factors than are some other vegetable proteins feeds. For example, cotton seed meal contains 2½ times as much vitamin B1, 2-1/6 times as much riboflavin and 1-1/6 times as much pantothenic acid as does soyabean meal. Cotton seed meal also contains more phosphorus than do other vegetable protein feeds, such as soyabean, linseed and groundnut meals. An increasing amount of cotton seed meal is being used as a source of protein in rations of growing chickens and turkeys. It supplies very effectively the added protein necessary for satisfactory growth when fed in a mash containing dried butter milk. Feeding of the correct amount of good quality feeds containing cotton seed cake at regular intervals during the work season, helps to produce efficient power from the minimum amount of feed.

Forms of Cake and Meal Used. Cotton seed cake is sold in India in the form in which it comes from the expellers or is broken into smaller pieces and filled in sacks. But in Western countries, it is ground and sold as cotton seed meal or the cakes are cracked and screened into different sizes known as nut-size cake (3/4″ to 1½″), sheep-size cake (5/8″ to 7/8″), pea-size cake (3/8″ to 5/8″) and pebble-size cake (less than 3/8″) to meet various requirements in the live-stock feeding industry. At the present time, cubed or pelleted cake is being increasingly used abroad as these have uniformity in size and are relatively soft. These are made by grinding the cake and pressing in a machine using the round or square dice to produce pellets or cubes, respectively. The cake is ground into cotton seed meal for use in mixed rations.

The marketing of cotton seed cake in the form of pellets or cubes has the advantage of needing only minimum packing space and the elimination of sacking. It can be adopted in India, provided the trade produces pure pellets, unadulterated with cheaper foreign material.

Comparative Nutritive Value of Cotton Seed and Cotton Seed Cake. In India, it is almost a universal belief among farmers that cotton seed is a much superior animal feed than cotton seed cake, though, of late, there is a definite trend to feed the milch animals with the cotton seed cake available in the urban areas from the mills. It may, therefore, be relevant to examine the available evidence regarding the comparative nutritive value of the whole cotton seed and its cake.

1. Almost all the nutritional authorities in India and the Animal Husbandry Commissioner to the Government of India have agreed that all the oil in the cotton seed (14 to 25 per cent., but usually between 17 to 22 per cent.) is neither necessary nor utilised by the animals for their nutrition.
2. While the Animal Husbandry Commissioner to the Government of India stated that the exact fraction of oil in the cotton seed utilised by the animal is still a moot point, the Memorandum of Human Nutrition *vis-a-vis* Animal Nutrition (1955), prepared by the Indian Council of Medical Research and the Indian Council of Agricultural Research consisting of four leading dairy and animal nutrition experts and three human nutrition experts, stated that oil cakes for feeding milch buffaloes should have about 10 per cent. of the oil to maintain the

present high level fat secretion in their milk. The Committee also recommended that 50 per cent. of the cotton seed produced could be safely crushed without impairing animal nutrition in the country.

3. Based on the feeding experiments carried out during 1953-54 at the Indian Dairy Research Institute, Bangalore, on the comparative nutritive value of cotton seed and cotton seed cake on milch buffaloes and cows, it was observed that although initially there was a significant increase in the butter fat content of milk when feeding was with cotton seed, the increase did not continue after 10 to 12 weeks.
4. Exhaustive feeding experiments were conducted on scientific lines at the Indian Veterinary Research Institute, Izatnagar, during the past four or five years on the comparative nutritive values of different oil cakes and of cotton seed and cotton seed cake. The results obtained showed that there was no significant difference between cotton seed and cotton seed cake in their nutritive value or on their effect on milk and fat production in cows.
5. The large-scale feeding trials carried out at the Government Military Dairy, Bangalore, in 1914 using nearly 90,000 pounds of cotton seed cake and 360,000 pounds of hulls per year on 40 animals (buffaloes, cows, bulls and heifers) gave excellent results. It was also reported that the animals took to the cake and the hulls and consumed whatever quantity was offered to them. The manager of the Military Dairy, who conducted these trails, stated : "There is no better feed as a concentrated ration for milch stock than cotton seed meal."
6. In the Western countries, cotton seed and cotton seed cake are valued mainly for their protein content : (*i*) comparative studies made on the nutritive values of the whole seed and the cake showed that the decorticated cotton seed cake contains 34 to 38 per cent. digestible proteins compared to 17 per cent. in the whole cotton seed (Morrison, 1942); (*ii*) animal fed with too large amounts of cotton seed may scour badly on account of the large amount of oil. In trials on dairy cows in the United States it has required 171 to 205 pounds of cotton seed to equal 100 pounds of high grade cotton seed meal; and (*iii*) the decorticated cotton seed cake is found to contain more than double the protein content of the whole cotton seed, as per the analysis conducted at the Oil Technological Institute, Anantapur.

From the evidence summarised above, it is clear that the cotton seed cake is a better feed than whole cotton seed even for the ill-fed Indian cattle.

MISCELLANEOUS PRODUCTS FROM COTTON SEED AND MEAL

Edible Products. As cotton seed is a large potential source of high protein foodstuffs, for which there is somewhat of a shortage generally in the world and as it is a rich source of certain vitamins and essential amino acids in which wheat and other cereal grains are naturally deficient, the possibility of utilising cotton seed on a large scale as a source of food for human beings is at present attracting considerable interest.

Cotton Seed Flour: To manufacture cotton seed flour, good seeds, uniform in size, well filled, free of field damage, damage by insects or deterioration through heating or storage, and containing not more than four to five per cent. immature kernels are selected. Cleaning and delinting of the seed is carried out in the usual manner, the delinted seeds are recleaned and hulled in a bar huller after which all but traces of hulls are removed thoroughly. The cleaned meats are flaked and cooked in a stack cooker at a temperature of about 225°F. for 70 to 100 minutes and pressed in hydraulic presses to remove the oil in the usual way. The press cake, after aging for a month, is ground, with air separation of the fine material, 98 per cent. of which should pass through a 200 mesh sieve. From a short ton of average cotton seed, about 300 pounds of cotton seed flour is obtained.

The flour has a relatively light colour and a pleasant and characteristic nutty flavour. The flour is used in the United States in a variety of baked products and confections. It is a concentrated source of proteins of excellent biological quality, and of minerals and vitamins of the B group. It is particularly valued for its large water-binding capacity in bakery and confectionery formulae of products with a high moisture content. It is remarkably stable in storage and is free of any tendency towards flavour reversion.

Other Edible Products: The flour when heated carmelises the natural sugars present and causes it to assume a deep reddish-brown colour. This heat treated flour has been widely used as a substitute for cocoa in baked products and confections and has also found considerable use as a base for synthetic cinnamon.

Technical Protein Products. The preparation of cotton seed protein adhesives, plastics and fibres are more or less still in the experimental stage. In the past, the technical development of such products was hampered by the lack of a raw material which had not suffered some degree of heat denaturation. Now that solvent extracted cotton seed meal will be available, efforts will have to be made to develop these products from the meal.

Cotton seed is the richest common source of the rare sugar, raffinose, which is used in the preparation of certain culture media. Raffinose may be obtained from commercial cotton seed meal.

Fertilisers. Though cotton seed cake is not known to be used as a fertiliser in India, 150,000 tons of the meal were used in 1941 as a fertiliser in the United States, largely as an individual fertiliser, but also in mixed fertilisers. The cotton seed meal used for fertilisers is naturally of low quality and includes a certain amount of inedible meal. Cotton seed meal and other oilseed meal fertilisers are valued for certain special purpose. They are particularly used in the United States in garden fertiliser mixtures, and for truck crops and tobacco grown in sandy soils from which inorganic fertilisers are inclined to lead badly. They decompose slowly in the soil and lack salinity and alkalinity. Cotton seed meal is recommended as a particularly effective fertiliser for fish ponds.

Solvent extracted cotton seed meal will be better suited as a fertiliser, as it contains much less oil than the expeller cake and will, therefore, decompose quicker in the soil.

LINTERS

Next in importance to oil and cake among the cotton seed products are the linters. In the United States, linters comprise about 13 per cent. of the value of the products. The amount of linters left on the seed as it comes from the gin varies considerably from 1 to 17.9 per cent. in India, against 3 to 18 per cent. in the United States. This variation is due primarily to the variety of cotton and to environments, including weather conditions, rather than to the methods of ginning. The amount of cotton linters removed from the seed varies according to: (*i*) amount of total linters remaining on the seed; (*ii*) market value of linters; and (*iii*) efficiency of the oil mill. Usually, three varieties of cotton linters, namely, the first-cut, the second-cut and the mill-run linters are produced. In the United States, the average quantity of linters produced was from 176 to 186 pounds per short ton, during the six year period from 1948-49 to 1953-54. During this period, the first-cut linters fell within the range of 24 to 28 per cent. of the total linter production. Efficient milling requires that residual lint on the seed should be around two per cent. or lower. It is common practice for oil mills in the United States to reduce the linters content to below two per cent. and in some cases below one per cent. when markets are favourable. When unfavourable markets prevail, a greater amount of linters is often left on the seed. Annually, more than a million bales (of 500 pounds) of linters are produced. In 1952 and 1953, more than 1.7 million bales were produced in the United States.

Preliminary cleaning of the linters is done in the mills, firstly, in the moting and the pneumatic lint flue collecting system and, secondly, in the lint cleaning machine, in which the lint is beaten over perforated metal screens in combination with pneumatic moting effects. By these devices, the dust, and big and small particles of the hulls are largely removed. This has resulted in a positive control of lint, so that it can be sold on the basis of its cellulose contents for chemical purposes directly. The linters are then pressed into bales and marketed.

Clean cotton seed linters are almost pure (88 to 96 per cent.) cellulose, but linters, as they leave the oil mill, contain many kinds of foreign matter in varying amounts which reduce the cellulose content. Foreign matter consists of particles in the inner lining of the bolls and hulls, leaves, motes, stems, dust and sand.

The United States Department of Agriculture set up in 1926 seven grades for cotton linters known as U.S. No. 1 to U.S. No. 7, which are differentiated according to the fibre length, the amount of foreign matter, colour and character. For the most part, first-cut linters fall into the first four grades, and the second-cut into the last three. Mill-run linters fall largely into the fourth, fifth and sixth grades.

Cotton linters probably have a wider variety of end-use markets than any other cotton seed product. Small amounts of first-cut linters, primarily grades one and two containing the long fibres, are used in the maufacture of medical supplies, such as surgical dressings, absorbent cotton and swabs (after bleaching and sterilising the linters), twine, yarns, mops and wicks. The remaining first-cut linters are used primarily in the batting (cotton sheets for use in quilts, etc.), padding and felting trade, such as automobile and furniture padding and bedding. For the batting trade, fibre length, resilience of the bat, yield of batting and colour are important factors. This class of linters is usually sold on actual samples. The second-cut linters are used largely by the chemical industry. About 60 per cent. of the total linters consumption in the United States is by chemical firms. These linters are composed largely of cellulose which makes it possible to convert them. The yield of chemical cotton (obtained by chemical purification of linters containing 98 per cent. of cellulose), the amount of foreign matter and the fibre length are vital to the manufacture of cellulose. For the chemical industry, the yield of cellulose is a very important factor in the purchase of linters. The yield of cellulose is determined by the official cellulose yield method of the A.O.C.S. The standard for cellulose content has been set at 73 per cent. The range may be from 65 to 85 per cent. Purchase discounts are allowed for cellulose below 73 per cent. and producer premiums for that above 73 per cent. Chemical uses for second-cut linters include rayon, artificial suede, paper-making (after purifying and bleaching), use as fibre material, plastics, explosives, meat casing, paints and lacquers (nitro-cellulose), cellophane, films, linoleum and storage battery cases. Wood pulp is the principal competitor for chemical grades of second-cut linters.

The consumers of linters may thus be divided into spinners, felters and chemical users. The utilisation of linters is based primarily on the relative proportion of the types (long and short staple) of the fibre present. The chemical users are the largest single consuming group. The felters are the next largest consumer. The superiority of cotton linters over other material for use as chemical cellulose is their high $\propto$—cellulose content and the high viscosity, high purity and excellent colour they impart to the chemical cotton. This superior cellulose is obtained from a selected mixture of second-cut linters, mill-run linters and/or hull fibre. These shorter fibres are preferred for their economy and ease in processing. They also yield superior cellulose.

United States is not only self-sufficient in its linters production, but also exports large quantities annually, mainly to the European countries for chemical use. Sometimes, it also imports some linters, mainly the long staple ones.

Production and Trade of Cotton Linters in India. The production and trade of cotton seed linters in India is in a deplorably backward condition. A good majority of the mills do not separate the linters at all from the seed in the milling process. The organised sector of the industry, though equipped for the separation of the linters and produces linters, sometimes crushes the seed without delinting, due to the lack of demand or low prices for linters and decorticated cotton seed cake. The present annual production of cotton seed linters in India is of the order of 600 tons. Formerly, the linters were mainly exported. But more recently, they are sold to one or two rayon mills in the country. Their use to the chemical industry (except for rayon) is practically nil. This is mainly because, as at present produced in the mills, the linters are found unsuitable and require preliminary treatment by the end-users. If the consumption of linters in India is to be increased, the oil mills themselves should resort to the production of first and second-cut linters and improve their quality by setting up cleaning units. Some standards should also be established for the marketing of linters. The felting (bedding, upholstery, etc.) trade and chemical industries should also co-operate by trying to utilise these linters.

HULLS

Cotton seed hulls are the least valuable of the cotton seed products, contributing only about three per cent. of the total value of the products. Cotton seed hulls vary in proportion between 40 and 50 per cent. of the weight of the whole seed in the United States. From an examination of six samples of different Indian varieties of the seed, the proportion of hulls is found to vary from 27.6 to 40 per cent. (including linters), on the weight of the whole seed. From the work done at the Central Food Technological Research Institute, on nine varieties of the seed, it was found that the proportion of the hulls in the seed varied from 36 to 44.4 per cent.

The yield of hulls in the processing of 12 varieties of *desi* and American type cotton seed obtained in 18 pilot plant runs varied from 28.7 to 42 per cent. (Desikan and Murti, 1959) including the residual lint left after delinting the seed. According to the report received only from one mill, the yeild of hulls varied from 26 to 32 per cent. In the United States, the six-year average (1948-54) yield of hulls was 22.6 per cent. No data is available on the total production of hulls in India. In the United States, the production of hulls annually for six years from 1948-49 to 1953-54 ranged from 857,000 to 1,338,000 short tons, which includes the weight of residual lint left on the hulls after delinting.

Physical and Chemical Characteristics. The cotton seed hulls are bulky, weighing approximately 10 lb. per cubic foot, the density depending upon the degree of delinting and the degree of packing. The hull is a horny material which forms the outer covering that encloses and protects the seed kernel. Cotton fibre is an out-growth from an outer layer of cells of the hulls, held fast between the relatively large cells. Chemically, cotton seed hulls consist of three major components : pentosans (22.3 to 38.4 per cent.), cellulose (42 to 46.6 per cent.) and lignins (17.5 to 25 per cent.). The average protein contents of the hulls is 3.3 per cent., oil 0.52 per cent., moisture 8 to 9 per cent., ash 1.8 per cent. and crude fibre 49.2 per cent. (Bailey, 1948u). Cellulose prepared from the hulls is similar to cellulose prepared from other sources. Lignin is the insoluble residue remaining after treating cellulose materials with 72 per cent. sulphuric acid.

Uses. Originally the hulls were used primarily as fuel for mill operation. In India, it is still used for this purpose in a large number of mills. But at present, the largest use of cotton seed hulls in the United States is as a source of roughage for feed for dairy cattle, beef cattle, sheep and work stock. The bulky nature of the hulls makes them especially suitable for mixing with concentrates in feeding cattle. Since concentrates are inclined to become heavy when moistened, the addition of hulls keeps such a mixture porous and thus more easily reached by the digestive juices. A popular mixture in the United States is 20 per cent. cotton seed cake and 80 per cent. hulls. Probably, 85 to 90 per cent. of the hulls produced in the United States are used in livestock feeding (Fetrow *et al.*, 1956). Hulls are classed as a low protein roughage and have a feeding value which is nearly equal to prairie hay, oats, or straw from wheat or rice.

The hulls are also used as a stuffing and packing material and soil conditioner. The bulky nature of cotton seed hulls makes them an excellent soil conditioner. The small amount of nitrogen and metallic salts, which contains large amount of calcium, magnesium, and potassium, has proved to be a satisfactory fertiliser. Cotton seed hulls are also used in small amounts in floor sweeping compounds, bedding materials and in road construction as fillers. In the chemical industry, hulls are used in making plastic and furfural.

Potential Industrial Uses. Considerable volume of work on the industrial utilisation of cotton seed hulls has been carried out in the United States. Xylose was produced from cotton seed hulls on a pilot plant in 1929; a sweeping compound based on cotton seed hull bran was developed in 1938; a highly effective activated carbon was produced from hull bran in 1939. The destructive distillation process was tried on the hulls in 1932 and 1940. Furfural manufacture from cotton seed hulls was tried and patents were taken. The hulls have been tried as a filler for phenolic moulding compounds. But it is doubtful if more than a very small fraction of the hulls produced in the United States are being used in these industrial channels. One of the important reasons for this is that the price that cotton seed hulls command in the United States as a roughage is too high to permit their extensive use in the chemical processing industries. As about 90 per cent. of the hulls produced are consumed as roughage, only about 10 per cent. of the hulls produced are available for other uses.

In India, the position is somewhat different. Though cotton seed hulls are being used to a limited extent as a roughage, probably due to the transport costs of this bulky material, a major part of them is used at present as fuel. Their use as fuel is not an economical proposition because they make poor fuel. It is desirable, therefore to popularise the hulls, firstly, as a roughage and, secondly, for use in chemical industries. From the experience gained at the Oil Technological Institute, Anantapur, cotton seed hulls are found to be a very popular animal feed. There is heavy demand for them whenever produced in the pilot plant there.

GRADING OF COTTON SEED AND ITS PRIMARY PRODUCTS

In order that the cotton seed milling industry may make steady progress, it is necessary to grade the raw material, cotton seed and cotton seed products. By grading cotton seed, the mills will be in a position to know the quality and the approximate quantity of the products obtained, on the basis of which the price of seed and the products can be fixed at reasonable levels. Otherwise, the mills which may make large profits in the early stages of the industry will pay very little or no attention to economy, either in the erection of plants or in their operation. More mills will be built in a hurry on unsound lines with a view to making large and immediate profits. The industry will soon come to a stage when the profits must come from efficient operation, supervision and stable operation. The mills that continue to waste money in the manufacturing departments may lose money on their investment, with the result that the industry will fail to prosper. In the end, both the producer of cotton seed (farmer), the miller and the consumer of the products will be at a disadvantage and the industry cannot thrive.

GRADING OF COTTON SEED

A necessary requisite for sound marketing of any commodity is a standard method of grading. Since individual lots of cotton seed may differ widely in composition, a reliable method of grading is essential for efficient marketing. The oil content of different lots of cotton seed may vary by more than 250 lb. per ton of seed and the meal or cake (41 per cent. protein content) by more than 450 lb. per ton of seed. These variations represent large values per ton.

The only basis on which cotton seed is sold at present in the market, either for milling or for other purposes, is mainly on physical examination. In some cases, the sale is based also on the oil content of the seed. This will not correctly evaluate the seed or the quality of the products. It is, therefore, necessary to lay down certain standards or grading. In this connection, the procedure followed in the United States, where the industry is placed on a sound and prosperous condition, can be a good guidance. In that country the rules for grading and evaluation were evolved and changed along with the development of the cotton seed crushing industry. The following extracts from the Agriculture Information Bulletin No. 39 (1951) of the U.S. Department of Agriculture, entitled "The Grading of Cotton Seed" summarise very well the development of the grading methods in the United States.

> "Early efforts to develop a grading system were based on physical inspection of the seed. In 1899, the inter-State Cotton Seed Crusher's association adopted rules defining 'prime' cotton seed and classifying all seed not meeting 'prime' requirements as 'off' seed. Among the methods adopted was the 'cut and count' method, which was based on the number of immature and damaged seed out of a sample of 100 random-selected seed. An additional rule provided for foreign matter reductions in excess of one per cent. Later methods included moisture in addition to immature seed, discoloured kernels and foreign matter; but the accuracy of such determinations was based almost entirely on personal opinion and frequently the discounts were excessive. No provisions were made for seed of better than average quality.
>
> The principal product of cotton seed is oil. It, together with the cake or meal produced, has represented from 77 to 90 per cent. of the total value of cotton seed products. Therefore, as might be expected, the quantity and quality of oil and cake or meal produced was considered to be the basis of a cotton seed grading program. With the advent of improved methods of sampling and chemical analysis a system of grading involving such principles was proposed.
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> In 1928, a forerunner of the present system of cotton seed grading was developed. The 1928 system was based on the principle that the quantity and quality of oil and cake in cotton seed should be the main determinants with respect to seed value. Studies of product values indicated that oil was from 3·3 to six times more valuable than cake. Frequently, one pound of oil was found to be equal in value to about five pounds of cake. These findings led to a suggestion that a quantity index might be developed on one to five ratio of value. A table was developed to convert total oil and cake into an oil equivalent. According to data available at that time, cotton seed averaged about 19·0 per cent. oil and 3·7 per cent. ammonia, indicating 380 pounds of oil and 875 pounds of protein (41·13 per cent meal per ton of seed. With meal one-fifth as valuable as oil, total oil equivalent in the average seed was 380 plus 175 or 555 pounds This served as a quantity index of 100. The quantitative index could then be calculated from the analysis of any lot of seed by using this method.
>
> Another table was developed with respect to losses due to free fatty acids as a quality index of cotton seed. This table was to be combined with the quantity index table to derive a table of relative values. The losses due to free fatty acids were reduced to a simple formula using 1·8 per cent. free fatty acids at the average breaking point between prime and off oils. (Later, the factors of moisture and foreign matter were made a part of the quality index.) From this method, the present grading techniques were developed.
>
> Early in 1932, recommendations were made for the present cotton seed grading system. In that same year, the Secretary of Agriculture issued an order establishing the grades, and methods of sampling, analysing, and grading cotton seed sold or offered for sale for crushing purposes in the United States. Since the standards were first published, the accumulation of data and experience has, on occasion, necessitated refinements, and revisions of the standards have been made from time to time."

As last revised in 1945, standards for the grades of cotton seed were defined as follows :

Determination of Grade. The grade of cotton seed shall be determined from the analysis of samples, and it shall be the result, stated in the nearest whole or half numbers, obtained by multiplying a quantity index by a quality index and dividing the result by 100. The quantity index and the quality index shall be determined as hereinafter provided.

1. The basis grade of cotton seed shall be grade 100.
2. High grades of cotton seed shall be those grades above 100.
3. Low grades of cotton seed shall be those grades below 100.

Determination of Quantity Index. (*i*) For cotton seed that by analysis contain 16.5 per cent. or more oil, quantity index shall be equal to four times the percentage of oil, plus six times the percentage of ammonia plus five (the last figure representing the average value ratio of the linters and hulls) and; (*ii*) for cotton seed containing less than 16.5 per cent. oil, the quantity index shall be equal to six times the percentage of oil plus six times the percentage of ammonia minus 28.

Determination of Qualitative Index. The quality index of cotton seed shall be an index of purity and soundness and is determined as follows:

Prime Quality Cotton Seed : Cotton seed that by analysis contains not more than one per cent. foreign matter, not more than 12 per cent. moisture and not more than 1.8 per cent. free fatty acid of the oil in the seed shall be known as prime quality cotton seed and shall have a quality index of 100.

Below Prime Quality Cotton Seed : The quality index shall be found by reducing the quality index of prime quality cotton seed (100) as follows :

1. Four-tenths of a unit for each 0.1 per cent. of F.F.A. in the oil in the seed in excess of 1.8 per cent.
2. One-tenth of a unit for each 0.1 per cent. of foreign matter in excess of 1 per cent.
3. One-tenth of a unit for each 0.1 per cent. of moisture in excess of 12 per cent.

Off-Quality Cotton Seed : Cotton seed which on analysis are found to contain 12.5 per cent. or more F.F.A. in the oil in the seed or more than 10 per cent. foreign matter or more than 20 per cent. moisture and foreign matter combined.

Below-Grade Cotton Seed : Cotton seed the grade of which when calculated according to the qualitative index is below 40 per cent. shall be designated as 'below grade cotton seed' and a numerical grade shall not be indicated.

The above standards for the grading of cotton seed established by the United States Department of Agriculture were based on the chemical composition of cotton seed. Methods of sampling and chemical analysis were perfected and standardised in collaboration with the cotton seed crushers, cotton seed laboratories and the American Oil Chemists Society. These standards are not mandatory. Even so, a large number of oil mills in the United States use these standards voluntarily and about 75 per cent. of the seed purchased by the mills was on the basis of the above standards, with premiums and discounts for variation. At the request of the cotton seed industry, the Cotton Branch of the Production and Marketing Administration, United States Department of Agriculture, has undertaken the supervision of sampling, analysing and grading of cotton seed since 1937.

Advantages of Adopting Standards of Grading.

1. The benefits of marketing cotton seed on the basis of grade accrue to the processors and sellers of seed, as also to the crushing mills, as it is on an equitable basis.
2. Premium grades would encourage the producers to take proper care in harvesting and handling, as well as, adopting planting and cultural methods which tend to increase the elaboration of oil and protein in the cotton seed.
3. Accurate sampling and grading enables the mills to pay the actual value of the seed received by them.
4. The analysis can be used as a check against the efficiency of mill operations. It actually helped in the United States in raising the standards of mill operations in recovering the maximum oil and proteins (cake) from the cotton seed.
5. Copies of each grade certificate issued by the licenced chemists are sent promptly to the United States Department of Agriculture. Licenced cotton seed samplers are required to furnish the names of the country and State, in which each lot of seed sampled by him was grown or ginned. Consequently, the Department of Agriculture has been able to issue market news reports for the benefit of the producers, ginners and crushers of the variation in the quality of cotton seed produced in every section of the cotton seed belt. Thus, for the first time in the history of the cotton seed crushing industry, the raw material consumed by it was placed on an equal footing as far as grade and market facilities were concerned with other farm products, such as corn and wheat.
6. The information contained in the cotton seed grade certificates issued by licenced chemists contains a great mass of statistical data, from which can be deduced the probable causes of the variations in the elaboration of oil and protein as well as of deterioration of these constituents.

As stated already, there is no sound or scientific basis on which cotton seed is marketed in India at present. The development of standards of grading in India, similar to those obtained in the United States but based on actual analysis of thousands of proper samples over a few years, will undoubtedly help to place the industry on a sound footing. The Ministry of Agriculture should, therefore, take the initiative in the matter and evolve the standards of grading cotton seed in consultation with the industry, the producers and the traders of cotton seed and research laboratories, for adoption on a voluntary basis.

GRADING OF COTTON SEED OIL

The setting up of standards for grading crude cotton seed oil is even more important than for grading seed or the cake, as the value of the oil is much higher than either of these two products. In this respect, some standards are used by the trade in India for the crude cotton seed oil and for what is termed 'washed oil'. The Indian Standards Institution has set up standards for washed oil and refined oil, but not for crude oil.

According to trade practice, an F. F. A. up to 2.5 per cent. and Lovibond colour (Y+10R) measured in ¼" cell lighter than 500 is acceptable for crude oil. For washed oil a maximum F. F. A. of 0.2 per cent. and Y+10R lighter than 25 is acceptable. For better quality oil, no premium is paid but rebates are made for oils exceeding the above limits. Crude oils exceeding five per cent. F. F. A. and 700 colour units will be rejected and washed oils may be rejected if the colour is deeper than 35. Oils for export are sold exclusively as washed oil on the basis of a maximum F. F. A. of 0.5 and Y+10R of 35 or below. Though a standard is set up for crude oil, it is understood that Indian refiners buy only washed oil and that no purchases of crude oil are actually made. The crushers usually do not have the proper equipment and personnel to make the preliminary refining of the oil to produce the so-called washed oil, without detriment to the further refining of washed oil. The need to establish rules governing the purchase of crude oil by the refiners and refining of it by themselves is keenly felt. For, most of the cotton seed crushers in India not only give alkali refining to crude oil but also lightly bleach it in order to get a satisfactory colour to meet the requirements of the washed oil standards, since by single refining alone they are not always able to reduce the colour to the required lightness. During this light bleaching, due to the heating of the oil to above 200° F., the colour of the oil is fixed and is found difficult to remove further by the refiners without entailing undue refining losses.

It seems, therefore, desirable to establish standards for the crude cotton seed oil in trade as is done in the other countries.

In the United States, the National Cotton Seed Products Association has framed rules incorporating standards and grades to regulate the transactions in cotton seed and cotton seed products, which are fair to all parties concerned. Flavour, odour, F. F. A., refining loss and colour of refined oils are the determining factors in their grading of the oils. Five different grades of crude oil are established: 'Prime', 'Basis Prime', 'Off', 'Reddish Off' and 'Low Grade'. In addition to these, there are the 'Expeller' and the 'Slow breaking types'. According to the current rules of this Association, specifications are given as to the manner of taking samples of crude oil for analysis from barrels, tank cars, tank trucks and storage tanks at the sellers' end, and handling them before despatching to the buyers. The samples should be tested for odour, and flavour, moisture or volatile matter, meal or impurities, F. F. A., refining loss and bleachability, and colour. For 'prime' crude oil, the flavour must not be decidedly rancid, musty, sour or bitter, and the oil should not exceed 3.25 per cent. in F. F. A. The 'prime' crude oil shall produce a yellow refined oil, with a colour not greater than 35 yellow and 7.6 red on Lovibond scale, when measured in a 5¼" cell. It should not have a refining loss above nine per cent. When bleached according to the official method, it should yield an oil, having a colour of 20 yellow and 2.5 red on lovibond scale. In the case of the 'basis prime' crude oil, which is the next grade, the refining loss should not exceed 16 per cent. Premium and deductions will be made according to the results of analysis. 'Off' crude oil is decidedly rancid, musty, sour or bitter and/or exceeds 3.25 per cent. F. F. A. It is tendered on a sample basis. Similarly standards have been fixed for the remaining grades.

GRADING OF COTTON SEED CAKE OR MEAL

Cotton seed cake is sold primarily on the basis of its protein content as it is considered to be a protein concentrate for animal feed. It used to be graded as 'choice', 'prime' or 'off', with the ammonia fixed at 8 per cent., 7.5 per cent. and 7 per cent., respectively, for the three grades. Subsequently, a new definition for prime quality cotton seed meal was established with a minimum 36 per cent. protein guarantee to be designated '36 per cent. protein, cotton seed meal, prime quality'. Higher grades are to be similarly designated on the basis of the protein guaranteed. The most common protein guarantee for cotton seed meal is 41 per cent. Smaller quantities are also sold with a guarantee of 43 per cent. and 36 per cent. protein content. A smaller quantity of 28 per cent. protein content cake or meal is also sold, as some mills do not remove the hulls from the seed but crush the whole seed in expeller machines, after delinting. The cake thus produced is to be sold under the grade 'whole pressed cotton seed' (sometimes termed as cold processed cotton seed cake) and is guaranteed for 25 or 28 per cent. protein and generally has 23 to 25 per cent. fibres.

The present grading and transactions of cotton seed cake is governed by the rules of the National Cotton Seed Products Association in the United States. According to the rules, cotton seed cake is defined as a product of cotton seed only, composed principally of the kernel, with such portions of fibre or hulls and oil as may be left in the course of manufacture and shall be graded and classed as follows :

Cotton Seed Cake, Prime Quality. The cotton seed cake, prime quality must be firm, but not flinty in texture, must not have a sour or musty or burnt odour, must be free from mold, and must produce when ground into meal 'prime' quality cotton seed meal. It shall be designated and sold according to its protein or nitrogen content. 'Prime' quality cotton seed meal must be finely ground, not necessarily bolted. It shall satisfy all the other requirements of 'prime' quality cake.

When necessary to guarantee fat, crude fibre and carbohydrate content in order to comply with State Feed Laws, the contents of these should be declared on the labels of the sacks. There should also appear on the labels the proper word for designation of the size of the cakes, such as 'nut-size cotton seed cake, prime quality' or 'sheep-size cotton seed cake, prime quality' or 'pea-size cake, prime quality' or 'pebble-size cotton seed, prime quality' or 'protein cotton seed cake screenings, prime quality'. In labelling solvent extracted flakes, meal or pellets, the tags should show that the product is 'solvent extracted' flakes, meal or pellets, as the case may be.

Cotton seed cake with 36 per cent. protein shall be termed '36 per cent. protein cotton seed cake, prime quality' and higher grades appropriately designated to reflect the guaranteed analysis.

Cotton Seed Cake, 'Off' Quality. Cotton seed cake not fulfilling the requirements specified for 'prime' quality cake shall be graded 'cotton seed cake 'off' quality'.

Cotton Seed Meal, 'Off' Quality. Cotton seed meal, which has a sour or musty or burnt odour shall be graded 'cotton seed meal, 'off' quality.

Rules regarding sampling for the hydraulic pressed slab cake and the sacked meal, sized cake and pellets are also established. The chemical analysis of the meal or cake for moisture, oil, portein (nitrogen) and crude fibre shall be determined by the official methods of the Association only. Flavour is given only as an opinion.

Cotton seed cake is not sold in India on the basis of nitrogen or any of the other above bases but merely by physical examination and on the basis of decorticated and undecorticated cake. The former contains between 35 to 41 per cent. protein and the latter between 20 to 25 per cent, since it is a whole pressed cotton seed cake, mostly even without delinting. The crude fibre in this cake will be much higher than in the decorticated cake. Therefore, the undecorticated cake is much less nutritive to the animal and fetches a lower price than the decorticated cake.

The grading and selling of cotton seed cake on its protein content and composition rather than on the basis of whether it is decorticated or undecorticated is not only rational but necessary.

GRADING OF COTTON SEED LINTERS

Cotton linters are defined in the Rules of the National Cotton Seed Products Association, U.S.A. as the residual fibres removed from cotton seed by mechanical processes. They include the following classes (which are also defined in the Rules): mill-run linters; first-cut linters, second-cut linters and chemical linters.

In the previous section, in reference to the utilisation of cotton seed linters, mention has already been made of the seven grades of linters set up by the United States Department of Agriculture and how these different grades are used in different trades. It has also been mentioned that linters, for use in chemical industries, are purchased on their cellulose content and purity basis (chemical linters).

Cotton linters are mostly sold on the basis of actual samples and subject to inspection and acceptance.

SOME ECONOMIC FACTORS OF COTTON SEED MILLING INDUSTRY AND FUTURE OF INDUSTRY IN INDIA

INVESTMENT NEEDS

A cotton seed mill is an elaborate industrial plant consisting of seed houses, mill buildings, products storage, offices and all the necessary machinery and equipment required for handling the seed from the time it is received at the mill until the products are marketed. The technique of cotton seed processing is more complicated and requires greater skill and experience than for the processing of most other oilseeds. The financial requirements for investment in both facilities and working capital are quite large. Substantial capital will be locked up in buying and storing the cotton seed requirements of the mill in the season. In addition, large sums of money are necessary to pay operating costs at the beginning of the season before the mill receives payment for its cotton seed products. The minimum investment for a modern cotton seed oil mill of economic size will be about Rs. 1.5 lakhs excluding the working capital. While the investment does not increase in porportion to the capacity, it differs with the type of equipment chosen. An absolutely economic unit of the expeller type should have a capacity of about 50 tons of seed per day of 24 hours, and the slovent extraction plant 75 to 100 tons. Although in the United States a vast majority of the mills have been operating on hydraulic presses, they are rapidly converted into the expeller (screw press) or solvent extraction type, since 1940. The latter types of mills operate more efficiently and economically. Therefore, the development of the industry in India should be based on employing heavy type expellers which give a better extraction than the standard mills or by installing solvent extraction units. Where standard type expellers are installed, it would be more economical to work them in combination with solvent extraction and when this is adopted, the capacity should be increased to the economic limit. In this case, considerable pre-treatment equipment of a specialised type for seed cleaning, delinting, dehulling and separation of the hulls from the meats and heavy flaking rolls have to be added to the mill.

The requirements of land, buildings and equipment for a cotton seed mill are much larger than for processing any other oil seed produced in India. A minimum of about 10 acres of land would be required. A number of seed houses, especially fitted with arrangements for forced circulation through the seed are required. Seed houses are usually constructed of galvanised iron with concrete floors, and are fitted with screw or belt conveyors operated by electric motors for moving the seed into and out of them. Apart from the seed storage buildings, the mill building is the largest structure and the processing centre of the cotton seed oil mill. These buildings contain all machinery and equipment for the cleaning department, linter room, bale press, huller or separation room, press room, meal room and feed plant. Meal storage is usually done in this building. The same is true of the solvent extraction mill, except that there is a separate building for extraction. In addition to the buildings, there are oil storage tanks, solvent storage tanks, fuel oil tanks (or coal stacks), electric power sub-station, water cooling tower and often a water tower itself. As a lot of money is invested in the cotton seed mills and the replacement value will be even greater, it is necessary to see that the mill is adequately insured. The insurance should cover fire. There should be extended insurance coverage of the buildings, machinery and equipment, the stored raw materials and the finished products, and furniture and fixtures. There should also be breakdown insurance on motors and engines and against boiler explosions, in addition to workmen's compensation insurance, and auto and truck insurance. In the case of solvent extraction mills, insurance is indispensable. For this mill, the insurance rate is much higher.

LABOUR REQUIREMENTS

Labour requirements at a cotton seed mill depend on a number of factors, snch as size, type, and layout of the mill, efficiency with which labour is used, utilisation of the mechanical handling equipment, crushing volume and length of crushing season, number of shifts operated, seed sterilisation, pelleting, feed mixing, sack or bulk shipment of the meal. The labour requirements of any particular mill during a crushing year vary from peak during the height of the seed receiving season, to a low point during the period when the mill closes after finishing crushing. The key people in the mill are kept on the pay-roll all the year round. Men working in the different departments of a mill should be given specific jobs and job titles. In the United States, hydraulic press mills require about 1.7 times the labour of screw press mills and about 2.2 times that of solvent mills. Solvent mills pay the highest wages and hydraulic mills the lowest. This is partly because solvent extraction mill employs mostly skilled labour. Even the expeller mills employ more skilled labour than the hydraulic presses.

MARKETING RISKS

One of the most difficult problems that faces the cotton seed milling industry, as it does to other oilseed milling industries, in the absence of price support is protection against price decline from the time cotton seed is received until products are manufactured and sold. The importance of protection arises because most of the seed is brought and stocked in the season (lasting three or four months) during which time only a small proportion of the seed is processed in the mill. The balance takes many months for processing and disposal of the products. Meanwhile, product prices may change considerably. Sometimes, there is no relation between the prices paid for the seed and sale price of the products. To reduce the risk involved, the mills may make forward spot sales of crude oil and meal and to a lesser degree of linters and hulls at the time the seed is delivered. On some occasions, the mills may use the futures market.

PRICE STRUCTURE

The marketing of cotton seed is not properly organised in India. The seed is sold either by the farmer to the consumer or to the gins who in turn do the selling. The production of cotton, and hence of the seed, is the most determining factor in the price of the cotton seed in any region. The wide fluctuation in cotton seed production appears to be the major factor responsible for the great variation of its price from year to year. However, cotton seed is still mostly consumed directly as cattle feed, for which *desi* type seed, with less lint content is preferred. The cost of this variety is always higher than the American type seed. Secondly, as the American type seed is largely preferred for the crushing, the price of this variety of seed, which was formerly much cheaper than *desi* type, is rapidly catching up with the price of the latter. The production of other oilseeds and oils also has an influence on the price of cotton seed in a given season. There is a general tendency for farm prices of cotton seed to increase as the season advances. However, the prevailing prices of cotton seed products set a general limit to the price which the crushing mills can pay. Generally, the cotton seed market is still a sellers' market.

Prices of Cotton Seed Products. One of the factors influencing the price of the oil is the volume of production of the oil, which in turn depends on the size of the cotton crop. But the price of the oil is determined more by other factors than the products of oil in any particular season. One of the most important of these other factors is the total production of edible oils and fats in the country. The general price level in the country is another such factor. The price of cotton seed meal (cake) is more closely related to the meal production (in the inverse direction) than that of the oil. But it is also influenced by the total production of the oilseed cakes. In the case of hulls, since their market is limited, both as regards its uses (as roughage and a secondary fuel) and geographically, production would be expected to exert a greater influence upon their price than upon the prices of other cotton seed products. As for the linters, being an industrial raw material, their price is more strongly influenced by changes in industrial activity. They are also influenced powerfully by the total production of linters. In India, the market for linters is at present very limited. Therefore, for export, their prices depend upon the world prices for cotton seed linters.

In general, the prices of cotton seed products are influenced by four factors: (*i*) movements of general price level ; (*ii*) volume of cotton seed products production; (*iii*) production of competing commodities; and (*iv*) demand. These factors are inter-related and their relative importance is by no means constant.

SIZE AND DISTRIBUTION OF MILLS

Complete and up-to-date information on the total number of cotton seed crushing mills and their installed and actual production capacities is lacking. However, it is estimated that only about five per cent. of the total seed produced is at present processed for oil and other by-products. In the location of the mills, two factors should be borne in mind. The first is the trend of cotton seed production in particular areas. In the United States many a mill, notably in Oklahoma and Texas, had been closed down or shifted in the past as the production of cotton seed in the areas in which the mills were located had decreased. The second factor is the historical pattern of the development of the industry. Mills may be located in the heart of the seed-producing area for want of adequate transportation facilities, since the bulky seed cannot be moved to centrally located mills. As transportation and marketing facilities develop, each mill will be able to extend the area in which it can purchase seed. Competition increases and those mills that are uneconomically located or designed or have relatively inefficient management will go out of business. This happened in the United States where the trend had been towards fewer and larger centrally located units. There, the only increase occurred in a group of mills crushing 20,000 tons or more seed per year. All other groups of mills had declined and the smaller the volume of seed crushed the greater had been the rate of decline. All mills with an annual crushing capacity of 5,000 tons or less can be classed as small, between 5,000 and 20,000 tons as medium, and 20,000 or more as large. Under this classification, in the United States since 1924-25, the number of small mills have decreased by 46.1 per cent. the number of medium-sized mills by 25.5 per cent. while the large mills have increased by 65.6 per cent. in number.

There are certain advantages and disadvantages in locating a mill in seed-producing rural areas. Cotton seed is a light and bulky material. A bushel (1.242 cu. ft.) of seed weights approximately 32 lb. compared with 56 lb. per bushel of corn or linseed and 60 lb. per bushel of wheat and soyabeans. The average railway freight car carries 28.9 tons of cotton seed, compared with 45.9 tons of linseed, 48.2 tons of corn or 50 tons of wheat. This bulkiness of cotton seed makes it uneconomic to transport seed for crushing purposes more than 200 to 250 miles. Actually, a major proportion of the average rail haul has been 75 miles and truck hauls average even less. An average rail distance of 75 miles and truck distance of 50 miles seems to be economical in India.

The estimated total annual capacity of the industry in the United States in 1944-45 was 10,870,500 short tons (about 90.1 lakh long tons) which is considerably in excess of the quantity of seed available for crushing. In recent years (before 1944-45), the industry has operated at only 40 to 45 per cent. of the potential annual capacity. Of the 382 active mills for processing cotton seed in 1944-45 season, 122 mills were operated for refining and further processing cotton seed oil into finished products, while only 260 mills produced crude oil. Here in India, though the installed capacity of cotton seed mills is not known, the installed capacity of the oil mills (power driven) of all types is estimated at 92.7 lakh tons, which is much in excess of the production of oilseeds. Only about one-third of the total installed capacity is being utilised at present. It is, therefore, necessary to plan carefully and properly when new mills for cotton seed crushing are proposed to be started.

BY-PRODUCTS AND JOINT PRODUCTS

Unlike the majority of agricultural commodities whose production responds generally to market demand, cotton seed production is completely dependent on the production of cotton lint, which is subject to an entirely different set of market conditions. Cotton is thus a joint crop of lint and seed. In terms of monetary income to the producer, it is estimated that the lint accounts for about 80 per cent. of the total value of the cotton crop compared with about 20 per cent. derived from the seed. The ratio of lint and seed produced from seed cotton varies from year to year, area to area, and with the variety of seed planted and the soil and climatic conditions.

The total yields of the four products (oil, cake or meal, hulls and linters) per ton in the United States for 10 years (1935-36 to 1944-45) are relatively constant with a variation of less than two per cent. between the high and the low yields (94.8 per cent. and 93.1 per cent., average 94 per cent.) during this period. But the average yields of individual products vary to a greater extent. Thus oil and meal yields show a variation of 6.9 per cent. and 6.2 per cent., respectively. The yield of hulls is more variable with a difference of 12.1 per cent. between high and low (average being 25 per cent.). The lint yields showed the greatest variation of 32.9 per cent. during the ten-year period. Similar detailed data is not available on the products obtained in the industry in India.

The primary object of crushing cotton seed is to recover the maximum oil, the oil being of greater economic value than all the other products put together.

To prevent too great an absorption and consequent loss of oil, it is necessary to remove the hulls. The removal of the linters is an essential first step for efficient mill operation, as any considerable quantity of linters on the hulls makes the separation from the meats difficult and also causes loss of oil. Another advantage of removing the bulk of the hulls and linters before milling is that the oil and the cake obtained will be of superior quality. In addition, linters and hulls will also be obtained. The crude oil accounted for 55 per cent., the cake 29 per cent., the linters 12 per cent., and the hulls 4 per cent. of the total value of the products per ton of seed in the United States for 10 years from 1935-36 to 1944-45. The importance of the oil, as compared to other products is thus readily apparent. It is, therefore, obviously to the mills financial advantage to obtain the maximum yield of oil per ton of seed processed. The case of hulls and linters is somewhat different. While the production of these is essential for the maximum recovery of oil, variation in output per ton is possible, within certain limits. The removal of the linters from the seed is one of the most expensive operations performed by the crushing mills. Therefore, when the price is high, the tendency is to increase the cut of linters per ton, and when the price is low, to remove only the quantity necessary for efficient milling. In periods of good demand for the cake, the tendency is to add more hulls to increase the quantity of cake produced.

SEASONABILITY OF INDUSTRY

Cotton seed crushing is highly seasonal in nature like most of the agricultural processing industries. Cotton picking season varies in different regions in India. In the South, the main picking season is from January to August; in Bombay, from December to April, in Madhya Pradesh and Rajasthan from October to January. Variation of a few weeks and even up to a month, either earlier or later, may occur from year to year in the same region as a result of variations in weather in the planting and growing seasons. Once cotton has opened, it is picked rapidly. The weather is the controlling factor here also. To prevent the lowering of the quality (with the consequent financial loss) of both lint and seed, it is necessary that cotton should be picked before wet weather sets in. Since practically all cotton is ginned immediately after picking, the rate of picking and ginning are practically synonymous. Ginners generally do not have facilities to store and preserve adequately large quantities of cotton seed, especially when the seeds are high in moisture. Consequently, cotton seed moves to the crushing mills within a few weeks to one month (or two at the most) after ginning. Due to this heavy concentration of seed movement to the mills within a few months of the year and because cotton seeds are perishable, the mills operate all the 24 hours of the day during the crushing season in the United States. Hence crushing is concentrated in a few months of the year like marketing of the seed. Some large mills, however, operate most of the year. In the United States during the period 1938-40, the number of 24-hour days operated per mill varied from 162 in 1937-38 to 113 in 1939-40. But this period varies from year to year depending upon the size of the crop and other local conditions, such as availability of labour and transportation facilities. In the rural and small town localities, labour, which is drawn from agriculture, return to farms when the crushing season ends.

The short operating season results in the industry's capital equipment being kept idle during a substantial part of the year. This equipment is not adaptable to operations other than oilseed crushing. However, it should be borne in mind that a cotton seed mill that operates for four or five months in a year, working at 144 or 168 hours per week, utilises its capacity to a greater extent than a plant operating for 45 hours per week thoughout the year. The latter is not necessarily assumed to have excess capacity and excessive cost even though its capital equipment is idle more than 70 per cent. of the total available working time. There are advantages and disadvantages in both the continuous operation during the season and intermittent operation thoughout the year. One advantage of the 45 hour weeks and the 10 month or 12 month season is that the productivity of a crew operating the year round can be raised above that of two or three crews working on a seasonal basis. On the other hand, 12 months operation requires the installation of considerable additional storage capacity and would also involve certain losses through the deterioration of the seed in storage. A single shift operation would also involve some loss in product income, since it is generally recognised that the yield of the oil is lower when expellers are cold and single shift would require the mill to start each day's operation with cold expellers. Therefore, it appears that the 45 hour weekly operating schedule would increase rather than decrease the cost of crushing cotton seed, without in any way increasing the utilisation of capital equipment other than the storage capacity. It would also a ppear, based on the experience of mills operating 24 hours throughout the year that the savings in many items of overhead cost and increased labour efficiency more than offset the additional costs involved on such a schedule. However, the fact that, in the United States a number of mills operating a relatively short season (on a 24-hour-per-day basis) are able to compete successfully with mills that operate throughout the year indicates that all the advantages do not lie with the latter. Perhaps, it will be to the best advantage to operate cotton seed in the season and to switch over to crushing such other oilseeds as are available in the region for the rest of the year. The alterations necessary for crushing such other oilseed will not be of a major character. In fact, in India, it would be advantageous for groundnut and other oilseed crushing mills located in cotton producing areas, to remodel their plants for crushing cotton seed also, without materially increasing the already superfluous installed capacity of the expeller mills.

STARTING OF CO-OPERATIVE MILLS

On the organisational side of the industry, the formation of co-operative societies to run the mills appears to be a new and useful direction in India. In the United States, during 1922-50, 15 co-operative associations, some consisting of individual farmers producing the seed and the other consisting of co-operative cotton gins made up of individual growers, were organised. Each society operated one mill. One of these mills was leased to private interests in 1950. During 1953-54, these mills crushed 5,00,167 tons of seed. The grower members agree to supply the seed produced by them at market rates. Democratic control by members is the basic principle of all these mills. They have their own marketing associations, also formed on a co-operative basis. The members of each co-operative association vary from 12 to 64 in the case of those formed by co-operative cotton gins and 25 to 100 farmers and 11 to 20 gins in the case of those formed by both individual farmers and co-operative gins. The total number of farmer patrons served by these 14 mills either directly or through member gins is estimated at 50,000. The chief advantage of this system is that the seed is practically wholly supplied by the member farmers or gins and as the seed buyers, receiving commission, are eliminated, the cost of obtaining the seed is considerably less for a co-operative mill than for a commercial mill. These mills are found to operate in the United States more efficiently than the average commercial mill. For example, it was found that during 1948-49 to 1953-54, an average oil yield of 17.3 per cent. was obtained by co-operative mills as compared to the average yield of all United States mills of 16.3 per cent. and an average manufacturing loss of 4.2 per cent. compared to 5.9 per cent. by all mills. The higher yields are considered to be partly due to the location of the mills and partly to more efficient extraction because of better equipment of the co-operative mills.

Therefore it seems very desirable that one of the future developments of cotton seed crushing industry in India should be in this direction.

FUTURE OF INDUSTRY IN INDIA

The cotton seed crushing industry in India is as yet in its infant stage. There is hardly any competition for the procurement of the seed for crushing purposes nor is there any dearth of the raw material in the country. The industry commenced with curshing the American type seed only, which constitutes at present about a quarter of the total seed production. But, of late, *desi* seed is also being crushed following the realisation that several varieties of *desi* seed also contain a high oil percentage and less lint which is an advantage for milling. The main technological improvement that should take place is the complete switching over of crushing the whole seed to the modern technique of mechanical pretreatment and crushing the meats only for the production of oil and cake. The employment of low-powered expellers (the so-called standard expellers) should either be substituted by the high-powered units to win greater oil from the seed or should be employed for pre-pressing followed by solvent extraction. The immediate development of the industry should be one of expansion to reach the target of processing 75 per cent. of the seed produced. With technological developments in efficient methods of milling and refining the oil, there will be a progressively increasing demand for oil and other products internally in the country and better scope for export of the surplus production, for edible and non-edible purposes. However, cotton seed oil, and to some extent the cake and the linters, will have to continue to be exported till adequate demand for them is found in the country. In fact, the advantages of the cake as a better animal feed than the whole seed are being realised and people prefer the cake to the seed for feeding their cattle. The complete utilisation of the linters in India will only be achieved with the development of other industries requiring cellulose and fibres.

The scope for development of the industry is very great. The mills need not be kept idle during the off-season, for in most of the cotton seed producing regions, alternate oilseeds, are also produced and these can be processed without keeping the equipment idle. In view of the lower oil content of the Indian seed than the North American seed and in view of the lower extraction capacity of the existing expellers, solvent extraction of cotton seed with or without pre-pressing should be resorted to in a large measure, especially as both petroleum solvents and alcohol can be made available in bulk from the Indian industry. Thus, the future development of the industry should be in the direction of modernising and expanding the infant industry both by resorting to the largest techniques of delinting, dehulling, etc., before crushing and solvent extraction. The industry should be provided with the necessary technological information and data through departmental research in the country.

ECONOMIC IMPORTANCE OF INDUSTRY TO COUNTRY

The revised target set up for attainment by the end of the Second Five-Year Plan is the production of 65 lakh bales of lint. When this target is achieved, the production of seed will be about 23 lakh tons annually, against the present production of about 14 lakh tons. From the present trend of production of *desi* and American cotton, it may be safely assumed that 30 per cent. of the total seed produced will be of American type and the rest of *desi* type by the end of the Plan period. From the data obtained from the mills on the yields of *desi* and American variety seeds, it may be assumed that the average yield of the products will be 13 per cent. oil, 45 per cent. cake, 5 per cent. linters and 30 per cent. hulls. When the above target is reached and if 75 per cent. of the seed is processed for oil, it will result in the production of 2,22,000 tons of oil, 7,70,000 tons of cake, 86,000 tons of linters and 5,13,000 tons of hulls, annually. At the prevailing market rates, the total value of these products will be about Rs. 54 crores. This compares with the total value of Rs. 143 crores of the products of the cotton seed crushing industry in the United States. Besides the large amount of wealth thus created, the full development of the industry will give direct and indirect employment to a very large number of persons in the industry and trade. It will also earn considerable amount of foreign exchange for a long time to come.

FUTURE RESEARCH WORK

Unlike other major oilseeds in India very little work was done, till recently, on the cotton seed and its products. Only about four per cent. of the total seed produced in India is at present crushed for oil, as compared to more than 85 per cent. of the seed crushed in the United States.. The crude oil produced in India is much darker than that produced in the United States. The storage of seed, both at the gins and subsequently at the mills, is not done in any systematic or scientific way. Therefore, the seed is liable for deterioration during storage. The removal of colour from crude oil is found to be one of the difficult problems urgently awaiting solution. The utilisation of the soap foots produced in the refining of crude oil is another pressing problem to be solved. While all the linters that can be recovered from the seed should be processed and utilised, there is not sufficient demand at present in the country for their consumption. They are utilised in the rayon industry to a limited extent. Other outlets should be found for the linters. While the hulls are the least important of the by-products, being only three to four per cent. of the total value of the products, they are at present used as roughage for cattle and as a secondary fuel. Therefore a more economic utilisation of the hulls should be developed. No attention, whatever, is being paid to the manufacture of suitable equipment in India for processing the cotton seed.

The following are considered as the more important lines of work that should be undertaken at the various research institutes, engaged in work on the cotton seed and its products.

The Seed.

1. Study of the nature and extent of deterioration in cotton seed under the present methods of storage at the gins and the mills, and to work out improved methods of storage to prevent deterioration in the quality of the seed.
2. Study of the present ginning practices and their improvements to produce better quality seed.
3. Determination of the optimum conditions of pre-treatment of the seed and cooking and pressing the meats for the maximum yield of good quality oil.
4. Comparative study of the crushing, as is done in India at present, and processing by the modern technique, with special attention to the yield and quality of the oil and the cake.
5. Study of the need and economics of delinting *desi* varieties of cotton seed from the standpoint of cost, use of linters, and the yield and the quality of the oil and the cake, in view of the reported lint content varying from 1 to 15.6 per cent. of *desi* type seed.
6. The relative advantages of direct solvent extraction and of pre-pressing followed by solvent extraction of cotton seed should be

studied with regard to the cost, yield and quality of the oil (regarding refinability and edibility) and the quality and utilisation of the cake.

7. Investigation on the yields of the four joint products; oil, cake or meal, linters and hulls and the manufacturing losses per ton of the main varieties of Indian cotton seed obtained by proper processing, with a view to setting up standards of efficiency of milling.

The Oil.

8. Investigations on the removal of colour and impurities from crude cotton seed oil and production of good quality refined oil. Towards this end, studies should be directed on the behaviour of gossypol and other pigments in the crude oil on storage, on refining and storage after refining, the problem of colour reversion, the suitability of wet and dry refining methods and finally working out the optimum conditions of refining the oil.
9. The relative advantages of continuous (centrifugal) and of batch refining of the oil should be throughly investigated.
10. The reclamation of cotton seed oil soap foots by conversion to acid oil, splitting and distillation to recover the fatty acids, and the residual pitch and their applications in the various industries.
11. Manufacture of industrial products like fatty acids, stearins, commercial stearic acid, and surface active agents from cotton seed oil.
12. Segregation of cotton seed oil into the more unsaturated and the more saturated fractions for use in different industries.
13. In view of the high phosphatide contents of cotton seed oil, investigations on the economic separation and utilisation of the commercially important lecithin from crude cotton seed oil should be carried out.

The Cake.

14. Studies on the conditions of production of high soluble protein content cake, with minimum quantity of the toxic material gossypol, to enchance its nutritive value.
15. Study of the suitability of deoiled cotton seed cake as a fertiliser.

The Linters and Hulls.

16. Investigation on the utilisation of cotton linters in different industries.
17. Investigation on the economic disposal of the hulls.

The Equipment.

18. At present almost all the equipment required for the mechanical pre-treatment and processing (with the exception of expellers) is being imported, and no serious attempts are being made to fabricate the necessary equipment in the country itself. It may be that some of the complicated equipment, like delinting and dehulling units, and stack cookers, may have to be imported for some more time to come. But the simpler equipments like seed

cleaning units, hull-beaters, flaking rolls, sediment screens and high-powered expellers should be manufactured in India by specialised workshops.

General.

19. Laying down standards for marketing and utilisation of cotton seed products.

Research, of both fundamental and applied nature, in connection with the various problems outlined above, should be conducted simultaneously. This can be done not by undertaking the work in any one or two institutions, but in several institutions working on many aspects of the industry in a co-ordinated manner. In fact, in the United States, where the greatest progress has been made in the industry, research in cotton seed and its products is carried on even now in laboratories run both by the Federal and State Governments and the industry. Only then can the industry look forward with hope and confidence.

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CHAPTER V

CONSUMPTION OF COTTON LINT

INTRODUCTION

From remote antiquity, India has been famous for her cotton and cotton fabrics. Even now, she occupies a unique position both as producer and consumer of cotton. As a producer, she has the largest cotton acreage in the world, and her production was next only to that of the United States of America until recent times, when Soviet Russia and China came into the picture. As a consumer of cotton, she is second only to the United States.

The use of cotton in the manufacture of fabrics dates back to pre-historic times. The fortunate discovery of a piece of cotton cloth in the ruins of *Mohen-jo-daro* has provided conclusive evidence of the knowledge of manufacturing cotton cloth possessed by the pre-*Aryan* civilisation of the Indus Valley of about 3,000 B.C. Unfortunately, similar historic evidence corresponding to later dates is not available, until we come to the sixth century B.C., when mention is made of the export of cotton fabrics from India. Heredotus (450 B.C.) mentions that Indians made clothes from the fleece of wild trees, which may be taken to indicate that cotton was not a cultivated crop at that time. The earliest mention of cotton as a cultivated crop is during the reign of Chandragupta Maurya in the third century B.C. From these two pieces of evidence, it may be presumed that the cultivation of cotton for the manufacture of fabrics may have commenced somewhere between 450 and 300 B.C. Whatever the state of the cultivation and industry at that time, contemporary records show that the glory of the Indian Textiles had spread to China, Egypt, Greece, and Rome even before the beginning of the Christian era. As early as 73 A.D., Pliny complained that India drained the Roman Empire of a hundred million sesterces (equivalent to 15 million rupees) a year. From these early beginnings progress has been steady, and the history of cotton in India, from these times up to the 18th century, is reputed to be one of leadership in the world in cotton growing and textile manufacture. Even today, cotton supplies the raw material for the largest industry in India. It is a national asset, providing direct employment to about 7,00,000 people, besides contributing annually to the Government substantial revenue in the form of export duty and excise duty, and being a source of valuable foreign exhange.

CHIEF TEXTILE AND NON-TEXTILE USES OF COTTON

The dominant position of cotton among textile fibres is mainly due to its versatility, which makes it suitable for a large number of uses. The wide range of variation in grades and staple, represented in each annual crop, with accompanying changes in prices, enables the manufacturer to select his raw material with a view to securing maximum economy as well as suitability for a particular end-use. Despite extensive research efforts of man-made fibre producers, it has not yet been possible to incorporate into any of them as many desirable properties as are inherently present in cotton. Besides, cotton is the cheapest of the apparel fibres.

Cotton has virtually no limitation on its uses. Called upon to clothe nations, it provides apparel for men, women, children and infants, ranging from the finest evening dresses to coarse overalls, from snow suits to bathing suits. Apparels made of cotton are suitable for day and night, summer and winter, sunshine and rain, work and play. In the realm of household furnishings, cotton adapts itself to a multiplicity of uses and tastes. It responds to bleaching, dyeing and other finishing processes, so that a great many varieties of beautiful and serviceable fabrics may be made from it.

The ability of cotton to undergo changes when treated with chemicals has opened many new avenues for its utility. The combination of an excellent, versatile and cheap fibre, with an ever increasing number of inexpensive chemical reagents, augers well for research to make new textile products from cotton through chemical modification. Various reagents may be used to effect colloidal, physical or structural changes, such as decrease or increase in the crystallinity or crystallite size, elongation, elasticity, lustre, chemical reactivity, etc. Besides, there are also numerous other methods for modifying cotton. One such is to apply polymers for obtaining permanent finishes to cotton fabrics. Synthetic resins have also been used to impart permanent effects to cotton fibres.

But to think of cotton only as a clothing material is to lose sight of its other applications. For a great majority of purposes, where strength and extensibility, combined with ability to withstand wear and tear of any kind are required, cotton is the most economic of the textile fibres. It is, therefore, used for a great variety of industrial purposes. The National Cotton Council of America lists more than 60 industrial uses of cotton. Into this exacting field of consumption goes nearly 40 per cent. of the output of the cotton mills in America, an amount equal to that required for apparel. The industrial purchasing agent buys cotton in accordance with standard specifications, and uses it for the manufacture of such diverse items as automobile tyres and machinery belting, furnishing fabrics and upholstry, filter cloth and shoe canvas, bags for cement and fertilisers, wrappings, roofings and deck covers, binding tape and cable insulation, ropes and twines, embroidery and sewing thread, lint binding and concrete curing mats, wadding and surgical dressings, etc. In this connection, it is interesting to note that in 1941 the United States Automobile Industry alone consumed 10,05,000 bales (478 lb. each) of cotton and cotton materials.

Other new and important outlets of cotton are developing fast. The recently developed cotton insulation is attracting considerable attention at present. Cotton insulation is a fire-resistant product possessing, in a high degree, properties essential to an insulating material.

A relatively new use of cotton fabrics is in building construction. Cotton-covered plywood is also finding important uses. It serves to prevent cracks and furnishes a base for paint or wall-paper.

Of the total world crop of cotton, nearly 20 per cent. forms what is called waste. One of the most important consumer of cotton waste is the Waste Spinning and Manufacturing Industry. Soft furnishing, such as curtains and upholstery, loose covers and sheetings, blankets and towels are made of yarns spun out of cotton waste. Other outlets for waste are in the manufacture of quilts and candle wicks, roller cloth and heat insulation, electric cabling and slipper linings. Yarn prepared from thread waste is used in ropes, twines and carpet manufactures. Yarns from the bump-spinning section of the waste industry are used in making mops, sponge cloth, dusters, cheap blankets, etc. The paper industry is another large consumer of low grade cotton waste. This is also used for linoleum, wall-boarding, wadding trade, etc. Plastic is yet another outlet.

Cotton linters obtained by delinting cotton seeds after ginning, provide cellulose material for gun cotton, rayons, lacquers, etc.

PATTERN OF COTTON CONSUMPTION IN INDIA

Eighteenth and Nineteenth Centuries. Though in the past India had a flourishing foreign trade in cotton textiles, there was little trade in cotton as such. Cotton was primarily grown for domestic consumption. This was the position until the 18th century which witnessed the consolidation of British power in India, and which may be said to be the turning point in the cotton economy of this country. The period synchronised with the industrial revolution in England, which increased her demand for raw cotton. The foundation of a vigorous textiles industry in that country lead to the strangulation of the industry in India.

Britain imported less than 10,000 bales of cotton in 1764 whereas her imports increased to 1,40,000 bales in 1801, India being practically the only source of all this cotton supply. During this period, Britain also started exporting cotton textiles to India, which competed very favourably with hand-made Indian cloth. The newly acquired political power of Britain was fully utilised to encourage this two-way flow of Indian raw cotton to Britain and of British manufactures to India. This was further aided by the opening of the Suez Canal, with the net result that the age-old Indian textile industry lost its foot-hold in its own home market. The handicrafts of the Indian artisan failed to compete with machine-made goods.

This process continued during the 19th century and exports of raw cotton to Britain reached their peak in 1866. Thereafter, although the demand from Britain began to decrease, due to increased imports of superior American cotton into that country, the demand from the rest of Europe increased. Japan also entered the arena during this period, and all these factors had their detrimental effect on the consumption of cotton in India. Yet, it was during this period that India slowly started her own cotton mill industry.

Although the first mill was built in 1818, in Calcutta, the industry got going after 1856. As a result, the consumption of cotton by Indian mills came to about 0.3 million bales in 1880, which increased to about 1.5 million bales at the end of the 19th century.

During this period, attempts were also made to improve the quality of cotton so that better cotton could be made available to Britain at a cheaper rate. American seeds were imported and tried in several parts of India during the 19th century. Most of these trials were unsuccessful until the Departments of Agriculture were established in each province in 1907.

Twentieth Century. Having reviewed the pattern of cotton consumption during the 18th and 19th centuries, some of the important fluctuations, in the past fifty years may now be considered.

In this connection, it may be mentioned that cotton consumption in India is closely linked with its production. It is also influenced by consumption in other parts of the world because it affects the exports. Further, as Indian mills consume a sizable quantity of foreign cotton, the imports of cotton also form an important item. The data relating to these items from 1878 onwards is given in Table 42. For the years before the partition of India, i.e., before 1947, the figures are the averages for each quinquennium commencing from the quinquennium 1878-83. Thereafter, they are given for each year. However, for the former period, the actual values for a particular year are recorded in a few instances, viz., for 1913-14, 1923-24 and 1938-39, as these correspond to some important landmarks like the commencement of the First World War, the establishment of the Indian Central Cotton Committee and the commencement of the Second World War, respectively. Similarly, years of importance in this regard during the later period are 1946-47 and 1947-48, the years before and after the partition of India, 1951-52, the commencement of the First Five-Year Plan and 1955-56, the commencement of the Second Five-Year Plan.

First World War—Before and After. It will be noted that the annual mill consumption was only 0.36 million bales in the quinquennium 1878-83, and rose steadily and rapidly by about 0.3 million bales each quinquennium, until it reached two million bales during the quinquennium 1908-13. This was more or less the figure at the commencement of the First World War. It will be noted that this corresponded to only about 40 per cent. of the production. The rest was exported to Japan, Europe, Britain, etc. Further, the bulk of the cotton production during this period was of short staple varieties. Japan was the principal country importing Indian cotton. Nearly half of the export from India went to Japan as this short staple cotton suited the Japanese industry well.

TABLE 42. PRODUCTION, CONSUMPTION, EXPORT AND IMPORT OF COTTON IN INDIA (400 lb. bales)

Year	Production of Indian cotton (estimate)	Consumption of Indian cotton by mills in India	Consumption of all kinds of cotton by mills in India	Exports from India (year ending 31st March)	Imports of foreign cotton into India (year ending 31st August)
	(year ending 31st August)				
1878-83	1,583,400	Not available	361,666	1,302,102	—
1883-88	1,692,400	do.	656,915	1,458,378	—
1888-93	2,384,400	do.	1,082,594	1,499,677	—
1893-98	2,432,200	do.	1,351,161	1,252,190	—
1898-1903	2,634,000	do.	1,596,932	1,365,880	—
1903-08	3,684,800	do.	1,923,839	2,069,268	—
1908-13	3,995,000	do.	2,019,199	2,192,896	—
1913-14	5,066,000	do.	2,143,126	2,975,364	—
1913-18	4,512,000	do.	2,145,464	2,578,872	—
a1918-23	4,586,600	do.	2,094,415	2,371,024	35,933c
1923-24	5,161,000	1,835,943	2,065,000	3,764,000	91,416c
1923-28	5,690,200	1,821,993	2,240,800	3,427,400	193,831c
1928-33	4,983,300	2,278,270	2,452,800	3,228,000	308,847c
1933-38	5,557,600	2,651,708	2,962,400	3,323,200	424,912
b1938-39	5,051,000	3,151,065	3,810,000	2,703,000	539,694
1938-43	5,393,000	3,630,109	4,206,400	1,911,600	553,553
1943-47	3,963,000	3,841,075	4,542,500	568,305	491,155
1946-47	3,566,000	3,215,154	3,857,488	911,221	554,383
d1947-48	2,188,000	2,863,450	4,210,882	1,171,643	632,206
1948-49	1,677,000	3,123,915	4,254,636	426,048	905,531
1949-50	2,628,000	2,544,174	3,684,885	329,680	888,395
1950-51	2,971,000	2,516,963	3,622,088	83,788	1,203,412
1951-52	3,133,000	2,987,453	4,071,471	131,640	1,194,049
1952-53	3,131,000	3,611,630	4,460,416	404,773	775,023
1953-54	3,965,000	3,888,748	4,607,821	199,686	650,748
1954-55	4,227,000	4,138,438	4,768,912	170,783	676,774
1955-56	3,998,000	4,365,456	4,968,707	689,605	660,083

a. Data for consumption of Indian cotton prior to 1922-23 may be taken to be approximately the same as the figures for consumption of all kinds of cottons, since only very little of foreign cotton was imported during that period.

b. Figures prior to 1937-38 include Burma.

c. Figures up to 1928-33 relate to the import of foreign cotton into Bombay only.

d. Figures from 1947-48 onwards relate to the Indian Union only.

Note: The various statistical tables given in this chapter have been collected from different authorities. Due to differences in the closing dates and estimates of these organisations, appreciable differences are sometimes noticed in the figures supplied by them even for the same item. Therefore, for discussions on a particular point, as far as possible, figures supplied by one authority who has specially dealt with the point, have been utilised.

During the War years and the next quinquennium, the annual cotton consumption in India remained at a steady level of about two million bales, although production and export declined somewhat. However, there was an increasing demand for superior qualities of cotton. As a result, the end of the First World War witnessed, practically for the first time, the import of superior foreign cottons into India for consumption. These were of the East African, American and Egyptian varieties. During this period, there was a small increase in the indigenous production of medium and long staple cottons amounting to roughly 33 per cent. of the total crop (Fig. 24).

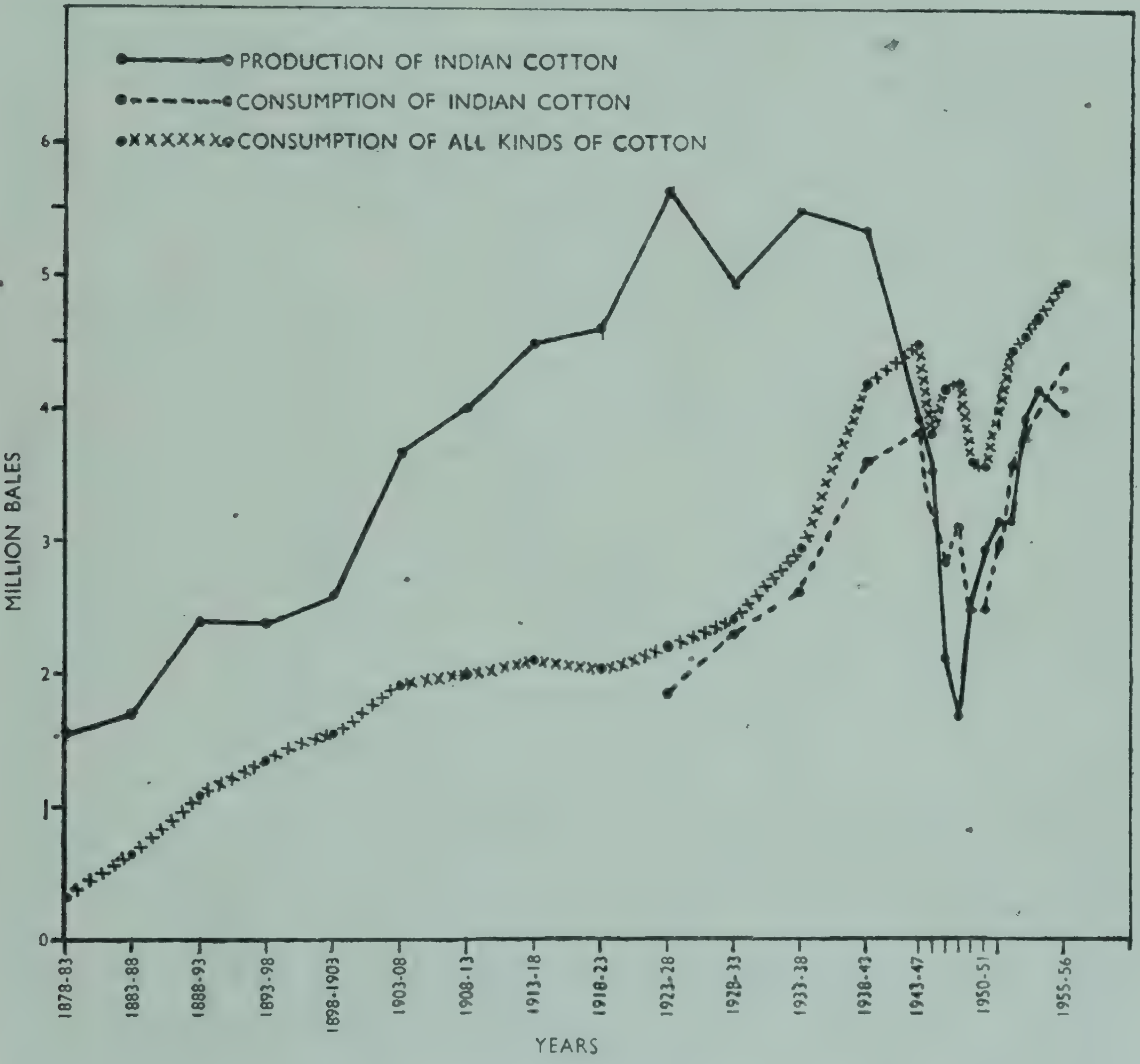

Fig. 24. Production and Consumption of Cotton

Establishment of Indian Central Cotton Committee. The next landmark in cotton consumption was the establishment of the Indian Central Cotton Committee. It has been stated above that there was a steady demand for superior qualities of cotton. To meet the demand, the Government of India enacted legislation setting up a Committee, called the Indian

Central Cotton Committee, in 1923, for the purpose of improving the cotton growing industry in this country, in general, and the quality of cotton, in particular. With the establishment of this Committee the problem of the improvement of cotton was tackled vigorously in all its aspects. As a result, the yield per acre, which was 96 lb. at the outset, was raised to 122 lb. in 1945; the area under improved varieties increased from 14 to 63 per cent. in 1946, the exotic varieties which yield more forming 33 per cent. of the total area.

Further, this period marked a steady increase in the consumption of cotton by Indian mills. From 2.24 million bales during the quinquennium 1923-28, consumption rose to 2.45 and 2.96 million bales in the next two quinquennia and reached 3.81 million bales in 1938-39 at the commencement of the Second World War. There was also a steady increase in the import of superior varieties; from 35,000 bales in 1918-23, imports rose to 1,94,000, 3,09,000 and 4,25,000 bales, respectively, in the next three quinquennia. The export figure remained practically steady at about 3.3 million bales during this period (Fig. 25).

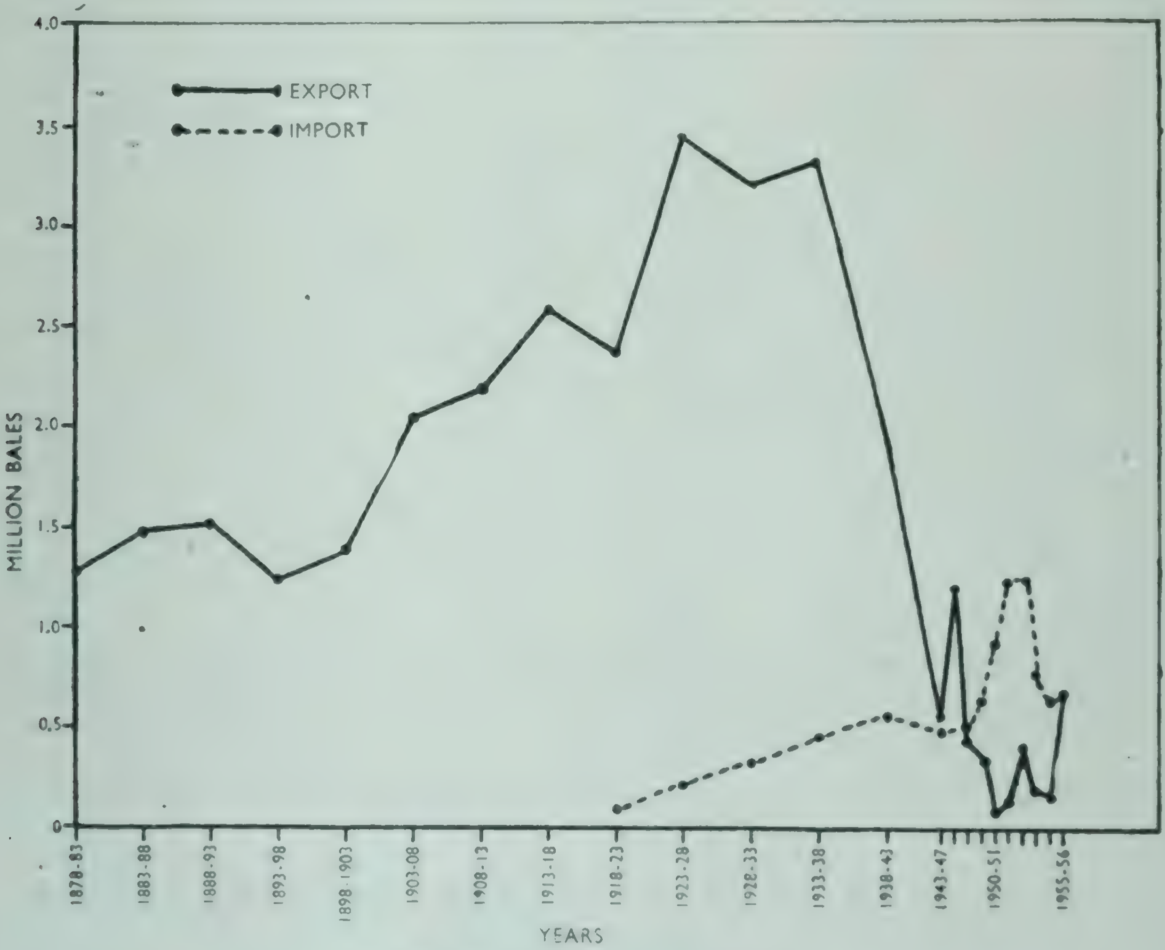

Fig. 25. Export and Import of Cotton

Second World War and After. The consumption increased rapidly after the commencement of the Second World War and averaged 4.3 million bales in the decade 1938-48. Imports of foreign cotton increased to more than half a million bales during this decade, while there was a rapid fall in the exports. From 2.7 million bales in 1938-39, the exports fell to 1.91 million in the next quinquennium 1938-43, and to 0.91 million in 1946-47 just before the partition of India. While the former of these falls was due to Japan's entry in the Second World War, the continuation of the trend was due to the 'grow-more-food' drive. Production, which was 5.39 million bales during 1938-43, also fell to a low figure of 3.57 million bales during 1946-47, on account of the reduction in area under cotton cultivation and the lack of demand from foreign markets.

Effect of Partition. The partition of the country dealt a severe blow to the cotton economy of India. Large tracts of irrigated land, growing long and medium staple cottons were lost to India, the loss in acreage amounting to 3.23* million acres, roughly 22 per cent. of the total area under cotton. Besides, these lands constituted some of the most fertile areas so that the loss in production was as high as 38 per cent. India was left with a total production of barely 2.6 million bales, while her consumption was more than 3.5 million bales, practically the same as before partition. This was due to the fact that almost all the mills (98 per cent.) were situated in the Indian Union. India had thus to depend on supplies of foreign cotton to the extent of 38 per cent. of her total requirements, and this, in the realm of medium and long staple cottons.

During 1947-48, production was 2.19 million bales, against a total requirement of about four million bales. The supply position became more stringent in 1948-49 due to adverse climatic conditions and reduced carry-over. Hence, in the years following partition, India was forced to import nearly one million bales, of which about half was from Pakistan.

Under these circumstances, India was compelled to augment her resources in the production of long and medium staple varieties of cotton, despite the high priority given to the cultivation of food crops during those years. Efforts were made in this direction by more intensive and scientific methods of cultivation of the existing acreage. These, however, met with limited success because of many reasons. Further, the cotton season of 1949-50 saw the total stoppage of imports from Pakistan, following the decision of her Government not to devalue her currency with the pound sterling. An acute shortage of cotton developed during this year, as the crop was small and the carry-over from the previous season, from which the deficit could have been met, had been reduced to the barest minimum. The supply position was insufficient to meet even the appreciably smaller requirements of Indian mills that year. Under the circumstances, the Government of India had to make special arrangements to import 1.2 million bales of cotton from foreign countries. The large recurring imports of cotton every year, which amounted to more than 30 per cent. of the country's annual requirements, involved a heavy drain on the finances of the country. This led the Government of India to take special measures for increasing production during the next season (1950-51). It not only permitted an increase of acreage but also raised the basic ceiling price besides providing facilities for irrigation, manure, etc. Yet, the actual production fell short of the targetted figure, being only 3.62 million bales in 1951-52.

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* For the purpose of the present discussion, the data given by the Indian Central Cotton Committee have been considered, as this topic has been dealt with by them thoroughly. These figures are somewhat different from those found in Table 42. However, the main conclusions are not in any way affected by the change.

First Five-Year Plan (1951-56). The Government's short-term plan to produce enough cotton to meet the domestic requirements of Indo-Pakistan varieties and of the essential export varieties was embodied in the First Five-Year Plan. The Plan envisaged additional production of cotton so as to reach the target of 4.2 million bales by 1955-56. As a result of the various measures adopted for cotton development, the production of cotton showed considerable improvement; the target was reached in 1954-55 itself, one year ahead of the schedule.

The production of long and medium staple cottons also rose during the same period, while that of the short staple cotton decreased to some extent. Further, the area under improved varieties of cotton also increased considerably during this period. It was about 13.6 million acreas in 1955-56 against 7.2 million acres in 1950-51, showing an increase of 87 per cent. Of this increase of 6.4 million acres under improved varieties, long staple accounted for 4.4 million acres.

Second Five-Year Plan. Although a major degree of self-sufficiency in respect of India's requirements of cotton of staple length less than 1-1/16" and also the production targets fixed under the First Five-Year Plan have been achieved, there is still need for increasing the production of cotton to meet the growing requirements of the Indian mill industry. Taking into consideration the expected increase in the population and the *per capita* consumption of cloth, a target of cotton production to the tune of 6.5 million bales has been fixed for achievement by the end of the Second Five-Year Plan.

It is reasonable to expect that this comfortable supply can be achieved in a few years, when the multi-purpose irrigation projects are completed, increasing the area under irrigated varieties and reducing the dependence on rainfall. We will return to this topic in a later section.

CONSUMPTION OF FOREIGN COTTON BY INDIAN MILLS

It has been pointed out that the bulk of the internal production of cotton consisted of short and medium varieties in the early years of this century. This necessitated the import of superior foreign cotton into the country for the manufacture of fine counts of yarn. The data regarding their consumption

TABLE 43. CONSUMPTION OF INDIAN AND FOREIGN COTTONS OF DIFFERENT ORIGIN IN INDIAN MILLS (400 lb. bales)

Year ending 31st August	Indian	Pakistan	Egyptian	Sudan	East African	American (United States and Peruvian)	Other foreign cottons	Total of all foreign cottons	Total consumption	Percentage of Indian cotton consumed	Percentage of foreign cotton consumed
1913-14	2,143,126	..	..	..	..	..	..	..	..	..	..
1923-24	2,037,000	..	3,000	..	..	4,000	21,000	28,000	2,065,000	99·0	1·0
1938-39	3,231,000	..	129,000	..	..	98,000	353,000	580,000	3,811,000	84·8	15·2
1946-47	2,144,671	*(1,016,836)	296,301	104,642	200,232	73,061	21,745	1,712,817	3,857,488	55·5	44·5
1947-48	2,863,450	723,216	305,697	88,870	195,315	26,463	7,871	1,347,432	4,210,882	67·9	32·1
1948-49	3,123,915	410,956	395,850	58,120	185,967	72,663	7,165	1,130,721	4,254,636	73·4	26·6
1949-50	2,544,174	203,442	403,082	30,482	281,503	206,967	15,235	1,140,711	3,684,885	69·0	31·0
1950-51	2,516,963	17,578	306,306	76,114	228,382	471,241	5,504	1,105,125	3,622,088	70·2	29·8
1951-52	2,987,453	4,185	157,524	63,216	162,868	694,547	1,678	1,084,018	4,071,471	73·3	26·7
1952-53	3,611,630	955	198,648	57,760	215,902	374,296	1,225	847,786	4,460,416	80·9	19·1
1953-54	3,888,748	368	279,139	66,093	211,550	159,009	2,914	719,073	4,607,821	84·1	15·9
1954-55	4,138,438	4,916	196,301	50,538	217,433	157,937	3,349	630,474	4,768,912	86·8	13·2
1955-56	4,365,456	..	186,759	122,883	251,875	32,539	9,195	603,251	4,968,707	87·7	12·3

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* This corresponds to the amount of cotton from the areas which went to Pakistan after partition.

are given in Table 43 (Fig. 26). It will be noted that, in the beginning, the quantity imported was almost negligible, being limited to a few thousand bales of cotton only. Substantial imports of superior foreign cotton began only after the end of the First World War. During 1923-24, about 3,000 bales of Egyptian and 4,000 bales of American cotton were consumed in Indian mills.

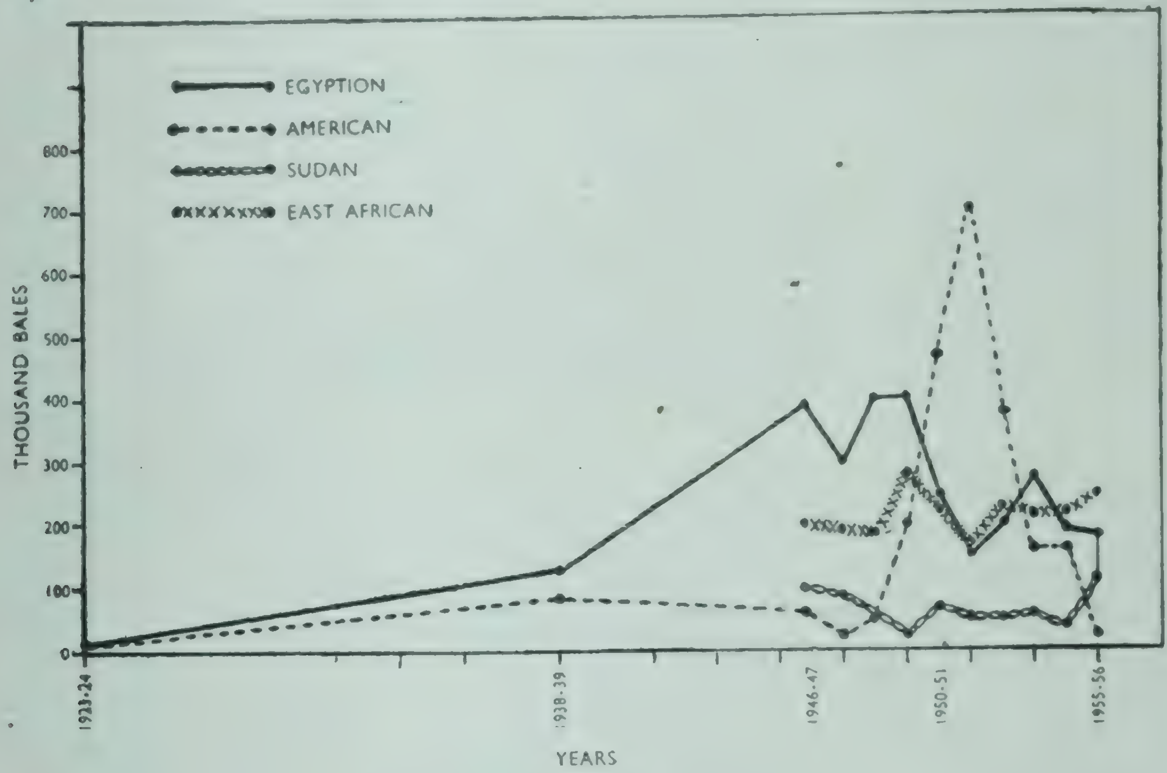

Fig. 26. Consumption of Foreign Cotton

Besides, it is presumed that some 50,000 to 70,000 bales of good quality East African varieties were also consumed during this time, since their import into India is on record. By 1938-39, consumption increased to about 1,30,000 bales of Egyptian, 98,000 bales of American and about 2,00,000 bales of East African cottons. By 1946-47 (year of partition) imports of Egyptian cotton rose to about 3,00,000 bales, that of East African remained at the same level of 2,00,000 bales while that of American decreased somewhat to 70,000 bales. During this year, about 1,00,000 bales of Sudan cotton were also consumed. Consumption in the area, which went to Pakistan later, was about one million bales, forming about 25 per cent. of the total consumption in that year. After partition, the quantity of Pakistan cotton, consumed in India, fell rapidly, so that after four years the figure barely touched 17,000 bales, becoming almost negligible in subsequent years. The Egyptian cottons, on the other hand, were consumed in larger quantities; about 4,00,000 bales during 1948-49 and 1949-50. Next year, their consumption decreased to the original level of 3,00,000 bales and during the subsequent five years, it fluctuated round about 2,00,000 bales except for a higher figure in 1953-54. The East African cottons also continued to be consumed at the rate of about 2,00,000 bales each year, although during 1949-50 it was somewhat higher. Consumption of Sudan cotton decreased gradually to about 30,000 bales in 1949-50, but thereafter it was maintained at 50,000 to 70,000 bales during the subsequent five years, with a rise, to about double the figure, in 1955-56. The consumption of American cotton, which was 73,000 bales in 1946-47, fell to 26,000 the next year. But, on account of the acute scarcity of superior varieties of cotton after the partition, arrangements were made with the U. S. Government to import American cotton in substantial amounts. As a result the consumption of American cotton reached the original level of 73,000 bales in 1948-49 and rose steeply to 2,07,000, 4,71,000 and 6,95,000 bales during the next three years, respectively. Thereafter, however, it fell to 3,74,000 bales in 1952-53 and to 1,59,000 during the next two years, with a further decline to 32,000 in 1955-56.

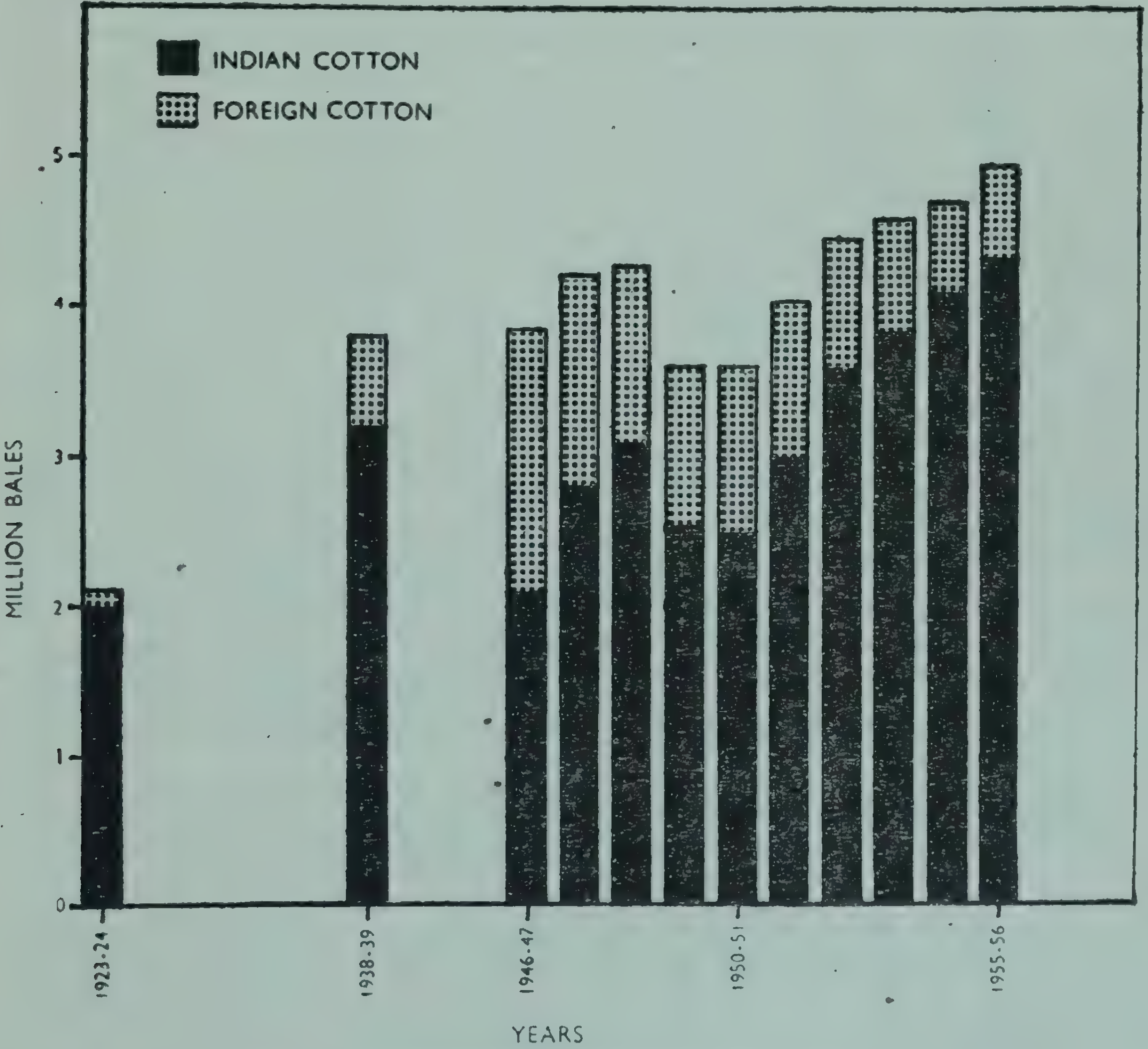

Fig. 27. Consumption of Indian and Foreign Cottons

Thus, the consumption of all kinds of foreign cotton, which was negligible before the First World War increased steadily to about 15 per cent. of the total consumption by the beginning of the Second World War. In the year after partition, it rose to 32 per cent. including the Pakistan varieties. During the next four years, it fluctuated between 27 and 31 per cent. However, afterwards there was a steady fall to 19 per cent. in 1952-53 and then to 16, 13 and 12 per cent. during the next three consecutive years. Thus it will be noted that dependence on foreign cotton is being reduced considerably; to about 12 per cent., the remaining 88 per cent. of the consumption being met by indigenous growths (Fig. 27).

CONSUMPTION OF COTTON ACCORDING TO STAPLE LENGTH

A notable feature of the Indian Textile Industry in recent years has been the increased consumption of long staple cottons for the manufacture of finer counts of yarn for meeting the demand for finer varieties of cloth from internal and external markets. Unfortunately, the data of cotton consumption according to staple lengths are not available. But it can be indirectly derived from the figures relating to the consumption of Indian cotton by varieties and of foreign cotton, which are available. For the purpose of the present analysis, all varieties of cotton consumed in India have been broadly divided into only two classes : (*i*) short staple cottons ; and (*ii*) medium and long staple cottons. Table 44 is prepared on the above basis.

It will be noted that there has been a continuous increase in the consumption of long and medium staple cottons. From 1.32 million bales in 1928-29, it rose to 1.85 million bales annually in next quinquennium 1929-34 and to 2.45 million bales in the quinquennium 1934-39. In terms of percentages, this accounted for 66 per cent. of the total consumption in 1928-29, while it rose to 72 per cent. and 76 per cent. in the quinquennia 1929-34 and 1934-39, respectively. In the years prior to partition, the total consumption of long and medium staple cottons was 4.06 million bales, which amounted to 86 per cent. of the total consumption in the quinquennium ending 1946. The actual consumption of long and medium staple cottons in 1946-47 was 3.47 million bales, which was 90 per cent. of the total consumption.

Though the partition of the country seriously upset India's production of cotton, it did not alter the pattern of its consumption. It, however, increased India's dependance on superior foreign cottons. Since 98 per cent. of cotton mills were situated in the Indian Union the demand for cotton continued to be the same even after the partition. The percentage of consumption of long and medium staples remained at the pre-partition level of 90 per cent. for two years immediately following partition, and then it began to rise steadily. In 1955-56, the total consumption of long and medium staple varieties was 4.79 million bales, which amounted to 96 per cent. of the total Indian consumption.

TABLE 44. CONSUMPTION OF COTTON IN INDIA ACCORDING TO STAPLE LENGTH

Year	Long and medium staple cottons (7/8" and above)		Short staple cotton (below 7/8")		Cotton of all staple lengths
	Thousand bales	Percentage	Thousand bales	Percentage	Thousand bales
1928-29	1,323	66	764	34	1,997
1929-34	1,852	72	704	28	2,556
1934-39	2,454	76	768	24	3,222
1938-39	3,280	86	530	14	3,810
1941-46	4,058	86	663	14	4,721
1946-47	3,471	90	386	10	3,857
*1947-48	3,791	90	419	10	4,210
1948-49	3,819	90	436	10	4,255
1949-50	3,418	93	266	7	3,684
1950-51	3,468	96	154	4	3,622
1951-52	3,926	96	146	4	4,072
1952-53	4,262	96	199	4	4,461
1953-54	4,391	95	217	5	4,608
1954-55	4,570	96	198	4	4,768
1955-56	4,788	96	181	4	4,969

* Figures from 1947-48 and after relate to the Indian Union only.

It will thus be seen that the total consumption of long and medium staple cottons increased from 66 per cent. in 1928-29 to 96 per cent. in 1955-56, and that the consumption of short staple varieties decreased correspondingly from 34 per cent. to 4 per cent., respectively, for the corresponding years. Credit for this achievement should go in a large measure to the Indian Central Cotton Committee, whose efforts have led to an increase in the production of long staple cottons in India (Fig. 28).

What has been stated above in regard to the increasing consumption of superior cottons in India is corroborated by data on the counts of yarn spun in Indian mills (Table 45).

It will be noticed that there has been a large increase in the production of all categories of counts. In the main production counts, viz., 11's to 20's, the increase is slightly more than double, from 347 million lb. in 1919-20 to 743 million lb. annually in the quinquennium 1951-56. In the next highest category of 21's to 30's, the increase is of the same order, from 184 million lb. to 355 million lb. for the same period. A similar rate of increase is also noticed in the lowest counts 1's to 10's, from 84 million lb. to 146 million lb. On the other hand, in counts of 31's to 40's, production has increased from 17 million lb. in 1919-20 to 206 million lb. in 1951-56, i.e.,

TABLE 45. YARN PRODUCTION IN INDIA BY COUNTS

Year ending 31st March	Counts 1 to 10's		Counts 11 to 20's		Counts 21 to 30's		Counts 31 to 40's		Counts above 40		Wastes, etc.		Average counts	All counts (million pounds)
	Million pounds	Per cent.	Million pounds	Per cent.	Million pounds	Per cent.	Million pounds	Per cent.	Million pounds	Per cent.	Million pounds	Per cent.		
1919-20	84·2	13·2	347·0	54·6	183·7	28·8	17·1	2·7	3·6	0·6	0·3	0·1	19·2	635·9
1919-24	90·4	13·6	358·1	53·9	195·4	29·5	16·9	2·5	2·7	0·4	0·4	0·1	17·6	663·9
1934-39	116·6	10·4	493·4	44·3	296·6	26·6	130·3	11·7	68·2	6·2	9·2	0·8	18·5	1,114·3
1942-47	168·8	10·8	797·8	51·1	327·7	21·0	159·0	10·1	90·2	5·8	20·2	1·2	20·1	1,563·7
1947-51	123·8	9·5	667·6	50·6	213·6	16·3	174·6	13·3	120·6	9·2	14·0	1·1	21·7	1,314·2
1951-56	146·0	9·3	743·4	47·5	354·6	22·7	206·2	13·1	101·6	6·5	14·8	0·9	21·4	1,566·6

Note: From August, 1947, figures relate to the Indian Union only.
Figures prior to 1935-36 include Burma also.

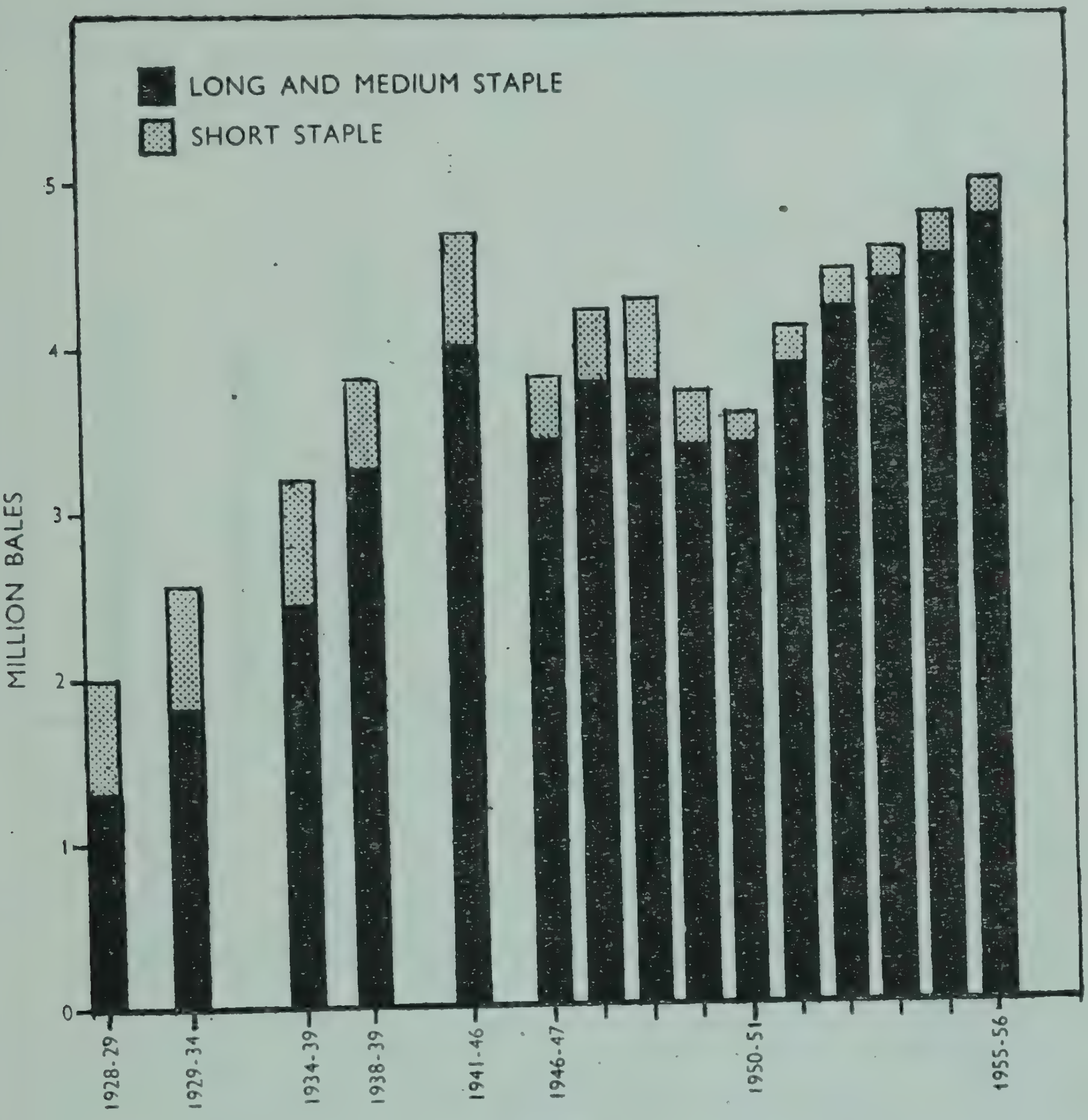

Fig. 28. Consumption of Cotton According to Staple Lengths

about twelve-fold. In the 40's and above, it has risen from about 4 million to 102 million lb., about 28 times during the corresponding period. This means that there has been a steady improvement in the production of finer yarns. This is further confirmed by the percentage production of the different types of yarn during these periods. The production of 1's to 10's counts was 13.2 per cent. in 1919-20, but was reduced to 9.3 per cent. in 1951-56. That of 11's to 20's and 21's to 30's was similarly reduced from 54.6 per cent. to 47.5 per cent. and 28.8 per cent. to 22.7 per cent., respectively. On the other hand, the production of 31's to 40's rose from 2.7 per cent. to 13.1 per cent., while that of 40's and above rose from 0.6 per cent. to 6.5 per cent. during this period (Fig. 29).

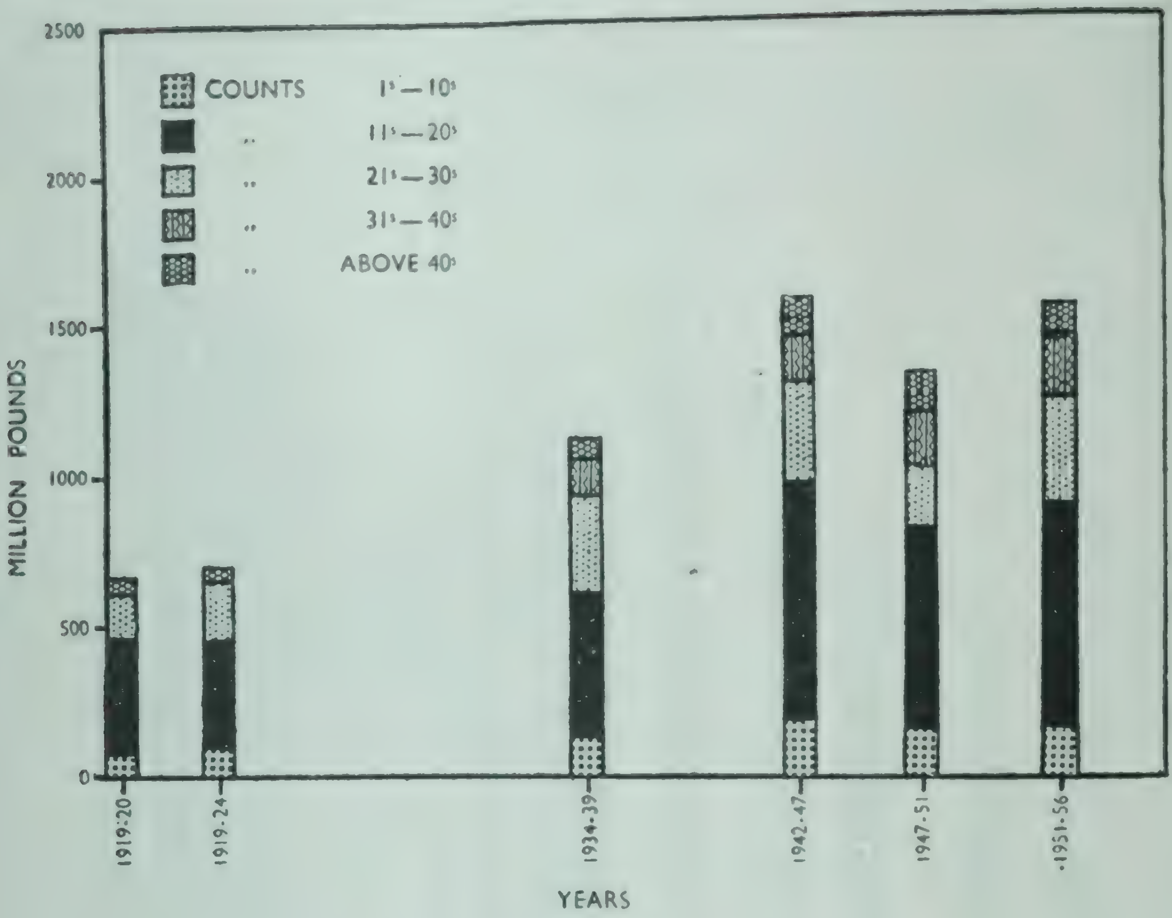

Fig. 29. Yarn Production of Different Counts

PRODUCTION, CONSUMPTION, EXPORT AND IMPORT OF CLOTH AND YARN

Although the first cotton mill was established in India in 1818, the real development of the cotton industry on modern lines dates only from 1856, when the Bombay Spinning and Weaving Mills was established in Bombay. This was followed by other mills in Bombay and Ahmedabad, and towards the end of the last century, there were no less than 156 mills equipped with a total complement of 36,000 looms and 40,46,100 spindles. The Swadeshi movement of 1906-10 gave a great impetus to the development of cotton industry in this country, and by 1914 the number of mills had increased to 239, equipped with a total complement of 90,268 looms and 63,08,758 spindles. On the eve of the First World War, India ranked as the fourth biggest cotton manufacturing country in the world.

The history of the industry during the past 50 years is not one of continued progress. The First World War enabled the industry to make some headway due to the restriction of imports from belligerent countries and to the increased outlet for production from Indian mills. But the menace of foreign competition, especially from Japan, witnessed immediately after the War, caused such a slump in the industry that it had to seek assistance from the Government. Table 46 contains the data for the mill production and estimated handloom production of cotton piece-goods in India, together with its imports and exports, in addition to the *per capita* consumption of cloth, from 1922-23 to 1955-56.

TABLE 46. PRODUCTION, EXPORT, IMPORT, NET AVAILABLE QUANTITY FOR CONSUMPTION AND PER CAPITA CONSUMPTION OF CLOTH IN INDIA (million yards)

Year	Mill production	Hand-loom production	Import of cloth	Export of cloth	Net available for consumption	Per capita available for consumption	Import of yarn (millions lb.)
1923-24	1,701	1,010	1,420	161	3,970	12·0	44·6
1923-28	2,048	1,222	1,684	174	4,780	14·3	51·0
1928-33	2,606	1,326	1,328	110	5,150	14·8	38·7
1933-38	3,514	1,324	796	106	5,528	15·9	32·2
1938-39	4,269	1,920	630	179	6,640	17·9	36·4
1938-43	4,230	1,698	364	476	5,816	15·4	21·2
1943-47	4,541	1,455	7	421	5,577	14·2	0·3
1946-47	3,890	1,350	16	350	4,900	12·2	0·2
*1947-48	3,770	1,230	26	200	4,820	14·1	8·7
1948-49	4,380	1,170	47	430	5,270	15·0	11·1
1949-50	3,850	1,140	73	710	4,450	12·6	14·2
1950-51	3,675	750	5	1,065	3,460	9·7	0·5
1951-52	4,296	1,160	9	956	4,600	12·5	1·8
1952-53	4,714	1,850	4	514	6,150	16·8	2·8
1953-54	4,964	1,500	5	554	6,010	16·4	2·3
1954-55	5,034	1,600	3	854	5,890	15·4	1·7
1955-56	5,101	1,509	10	680	5,940	16·5	2·9

* Figures from 1947-48 relate to the Indian Union only.

It will be noted that out of a total consumption of 3,970 million yards of piece-goods in India in 1923-24, about 43 per cent. was supplied by indigenous mills production, 25 per cent. by handloom production and 32 per cent. by imported piece-goods. The net available cloth for *per capita* consumption was only 12 yards at that time. The history of the industry during the subsequent years was one of continuous fight against Japanese and Lancashire interests, and representations to the Government for tariff protection to the Industry. The recommendations of the Tariff Board for duty on imported yarns and abolition of excise duty on all goods manufactured in India helped the industry to some extent (Fig. 30).

Nothwithstanding serious labour trouble in many centres of the industry, the cotton textile industry made marked recovery both in the internal and the external markets. The chief factors that helped this recovery were

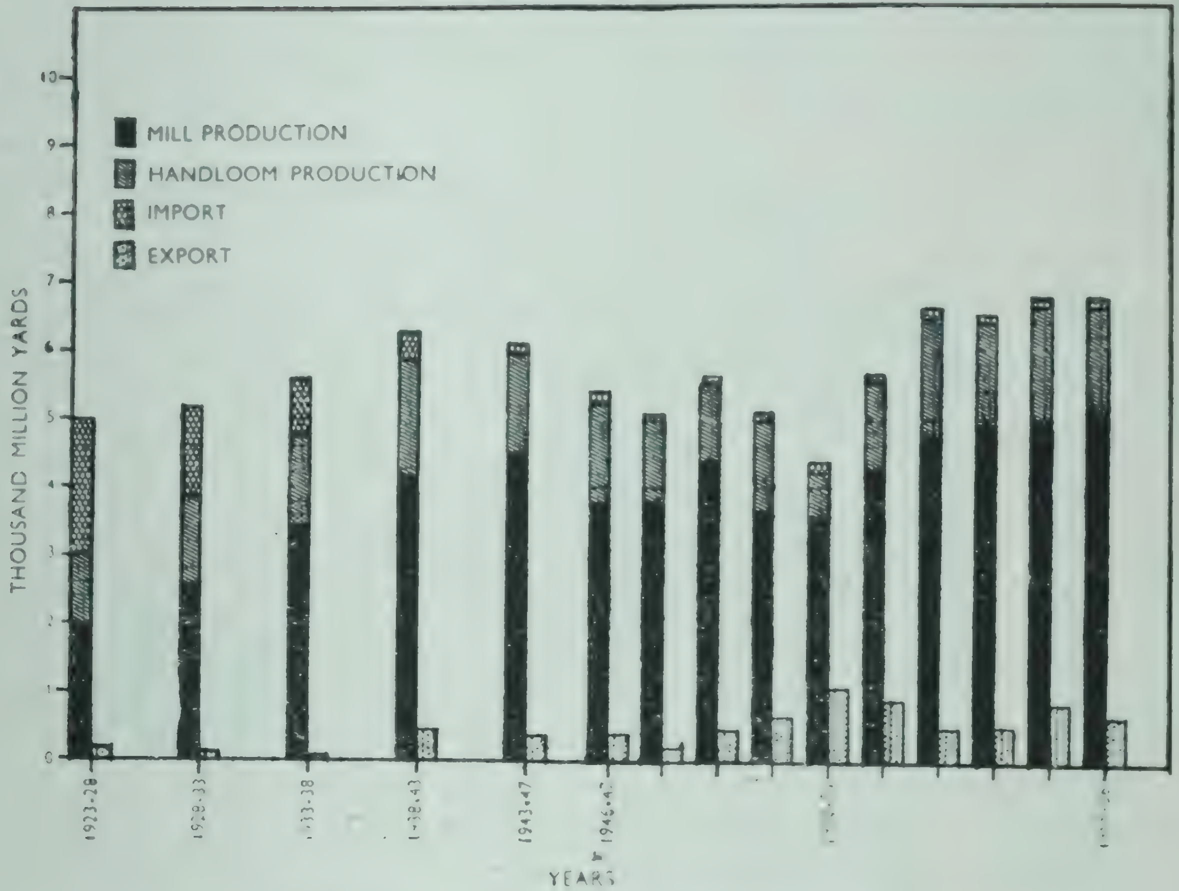

Fig. 30. Production, Imports and Exports of Cloth

the Sino-Japanese conflicts, which curtailed Japanese production and shipment to various markets and Lancashire's inability to fill the void, due to the higher prices of Manchester goods. The Indian cotton goods thus gained ground in markets, which were the monopoly of Japan. As compared to 1923-24, production by the mills showed a progressive increase. During 1938-39, it attained a record of 4,269 million yards of cloth. This amounted to an increase in the production of piece-goods in millls by 150 per cent. over the 1923-24 level. This increase was not due merely to the reduction of Japanese imports, but also to the increased demand for Indian goods from abroad. The increase in handloom output for the corresponding years was from 1,010 million yards to 1,920 million yards or nearly 90 per cent. The *per capita* available cloth was 17.9 yards (Fig. 31).

As against this progressive increase in production of piece-goods by the Indian mills, a precipitous fall is noticed in the imports of piece-goods during this period, from 1,420 million yards to 630 million yards. (The large import value of 1,200 million yards seen during 1932-33 was, however, mainly due to the heavy importation of Japanese goods to India during the year, on account of the depreciation of the Yen.) A similar fall is also noted in the imports of yarn into this country; while during 1923-24 it totalled 44.6

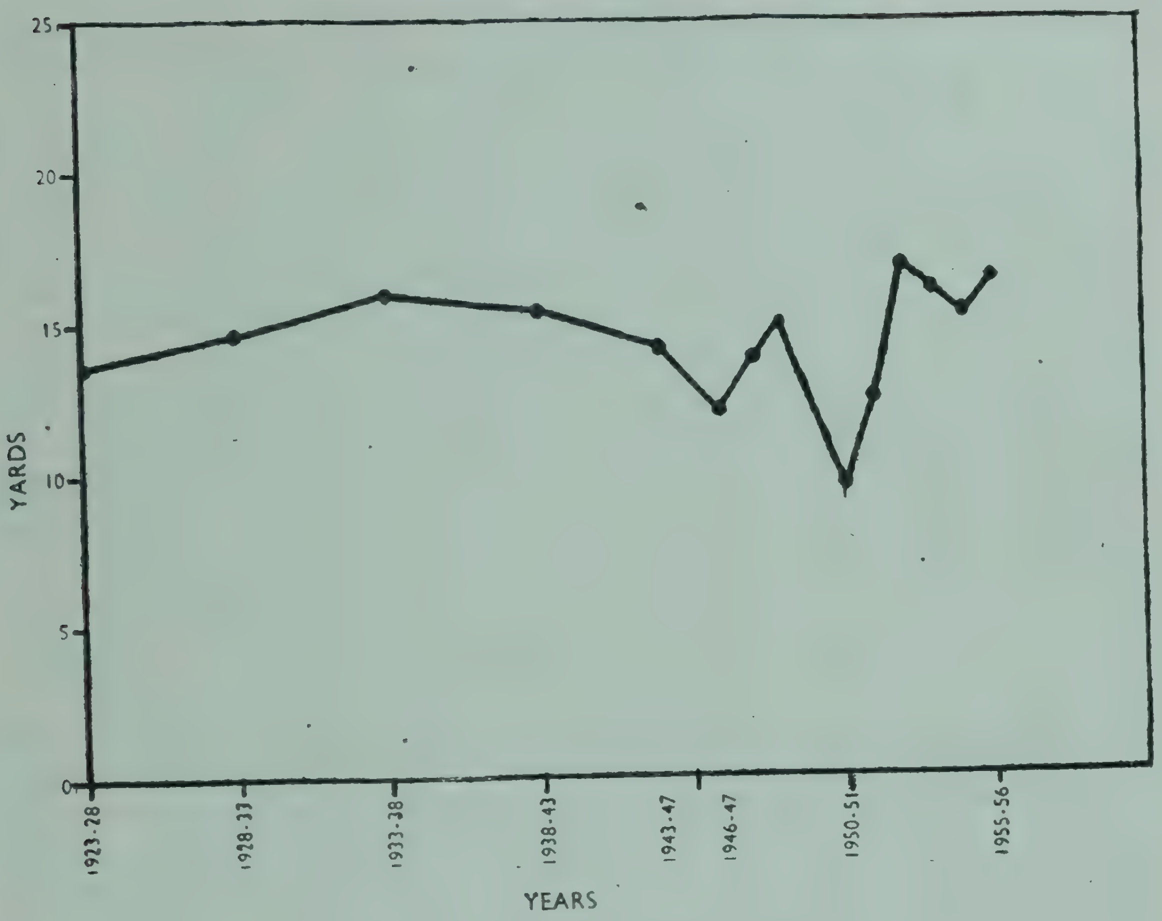

Fig. 31. *Per Capita* Availability of Cloth

million pounds, in 1938-39 it dropped to 36.4 million pounds. Thus, not only did the imports of cloth and yarn fall substantially, but the exports of Indian fabrics rose during this period. India, which was primarily an importer of cotton piece-goods, began to export them.

The export of piece-goods was, however, low up to 1935-36. It was 71 million yards that year. There was a progressive increase subsequently and, in 1938-39 it stood at 179 million yards, an increase of about 150 per cent. over the 1935-36 value.

However, there was a marked reversal of conditions in the earlier part of 1939. The low commodity prices that prevailed had their repercussions on the piece-goods and yarn markets with the result that the demand was very poor. In consequence, there was a heavy slump in prices and the industry fared so badly that huge losses were noticeable in the working of most of the mills. The additional duty on raw cotton and a reduction of import duty on Lancashire goods also came at this time. Sorely disappointed, the industry thought of curtailing production as the only solution of the problem. The Second World War broke out just then, and the situation changed for the better. With the outbreak of War it was hoped that the Indian cotton mill industry would receive a great fillip, but these hopes were not fulfilled.

Compared to conditions in 1914, the country was more self-sufficient in the supplies of textile goods in 1941. The industry, therefore, did not get much scope for expansion. Moreover, price control, excess profit tax, etc., stood in the way of the industry's progress. But the War opened new avenues for the development of the export trade. The industry was enabled to make gains by way of meeting the cloth needs of the Empire and allied countries.

During the War, the Government started buying increased quantities of cloth for the defence services. The War orders accounted for nearly 35 per cent. of the Indian production. The balance of 65 per cent. of the Indian mills' production was not enough to meet internal consumption, and it was found necessary to place restrictions on exports from the country. Due to controls and War-time difficulties, the *per capita* consumption of cloth fell to as low as 12.2 yards in 1942-43. To remedy this state of affairs, measures for increased production of cloth and reduction of prices were necessary. But the exigencies of War prevented an increase in production. On the other hand with a rapid rise in the people's purchasing power, complaints regarding cloth famine came from all over the country.

The War ended in 1945-46. With the cessation of War orders, it was thought that more cloth and yarn would become available for consumption. But continued labour troubles and reduction in working hours from 54 to 48 a week adversely affected mill production and hence the prices and distribution of cloth and yarn continued to be under control. Distribution was further affected by the calamities that followed partition. The price of cotton increased but there was no corresponding increase in cloth prices, which were controlled. The situation eased a little only after the Government referred to the Tariff Board the question of increased cloth prices.

With the removal of War-time controls, it was expected that there would be a steady improvement in the textile production in India. In fact, 1951-52 was a year of steady progress in the textile industry due to smooth industrial relations and easy availability of raw cotton. But all of a sudden, prices of raw cotton and other commodities, figuring prominently in the export trade, slumped to an unexpected extent. The competition in the export market became keen. The mills were faced with the problem of disposing of large stocks that had accumulated. Though the textile output (mill and handloom) in 1951-52 amounted to 4,296 million yards, the *per capita* consumption fell from the pre-War level of 17.9 yards to 12.5 yards, mainly due to the inability of the consumer to make increased purchases. It was under these circumstances that the First Five-Year Plan was started. The plan envisaged an increase in the *per capita* consumption of cloth to 16.5 yards without any appreciable change in the weaving capacity of the mills.

The record of the textile industry during the period of the plan is an impressive one. It not only achieved the target of cloth production envisaged in the development programme, but exceeded it by a comfortable margin.

The output of cloth in 1955-56 amounted to 5,101 million yards against the target of 4,700 million yards set by the planners. The output of yarn in 1955-56 also reached the target within a very small margin, the actual output being 1,630 million against the target of 1,640 million.

A gratifying feature of the textile position in India is the admirable manner in which the handloom and powerloom industries have risen to the occasion to come to the rescue of the consumer. These great allies of the organised mill industry have done very well under the First Five-Year Plan. The production of handloom cloth moved up from 750 million yards in 1950-51 to 1,509 million yards in 1955-56, which was short of the target set for it by about 200 million yards. The point worthy of attention is that the total production of cloth, mill and handloom combined, stood at as high a level as 6,610 million yards as compared with 4,425 million yards in 1950-51.

The *per capita* consumption of cloth, which was 9.7 yards in 1950-51, increased steadily year by year and stood at 16.5 yards in 1955-56. It is expected to rise to 18.5 yards at the end of the Second Five-Year Plan.

The prospect or threat of replacing cotton by man-made fibres has often depressed cotton growers all over the world. Many new fibres have been manufactured after the advent of viscose rayon in the early years of this century. But most of them have disappeared or have ceased to have commercial importance. Some of the earliest, however, persist and they have been making a headway since the first decade of the present century; for example, viscose, and acetate. In addition, some new fibres like nylon, terylene (dacron), etc., have also come into prominence in recent years. The data, in Table 47, show sthe progress of world production and consumption of cotton and man-made fibres (Fig. 32).

The figures indicate that though cotton production has been generally increasing, the increase in that of the man-made fibres has been faster. The production of the latter has become sizable only in the last ten years. However, their production totalled 5,929 million pounds in 1956, which is more than double the 1949 output. All sections of the man-made fibre industry have contributed towards this increased production . Further, man-made fibres continued to fare much better than cotton in competition for markets. In the last two years, rayon consumption was better than that of cotton in all principal countries except India, where the synthetic fibre industry is yet in its infancy. The position of cotton would have been more unfavourable, had it not been for its increased production in a numbr of countries in Asia, Africa and Latin America, where cotton textile industries are gaining in importance. Although the share of cotton in the world textile markets is extremely large, cotton's proportion continues to decline. It fell from 77 per cent. in 1937-38 to 69 per cent. in 1949 and 64.4 per cent. in 1957, while the share of man-made fibres increased from seven per cent. to 10 per cent. and 25 per cent. in the same period. Additional plants are being installed in many

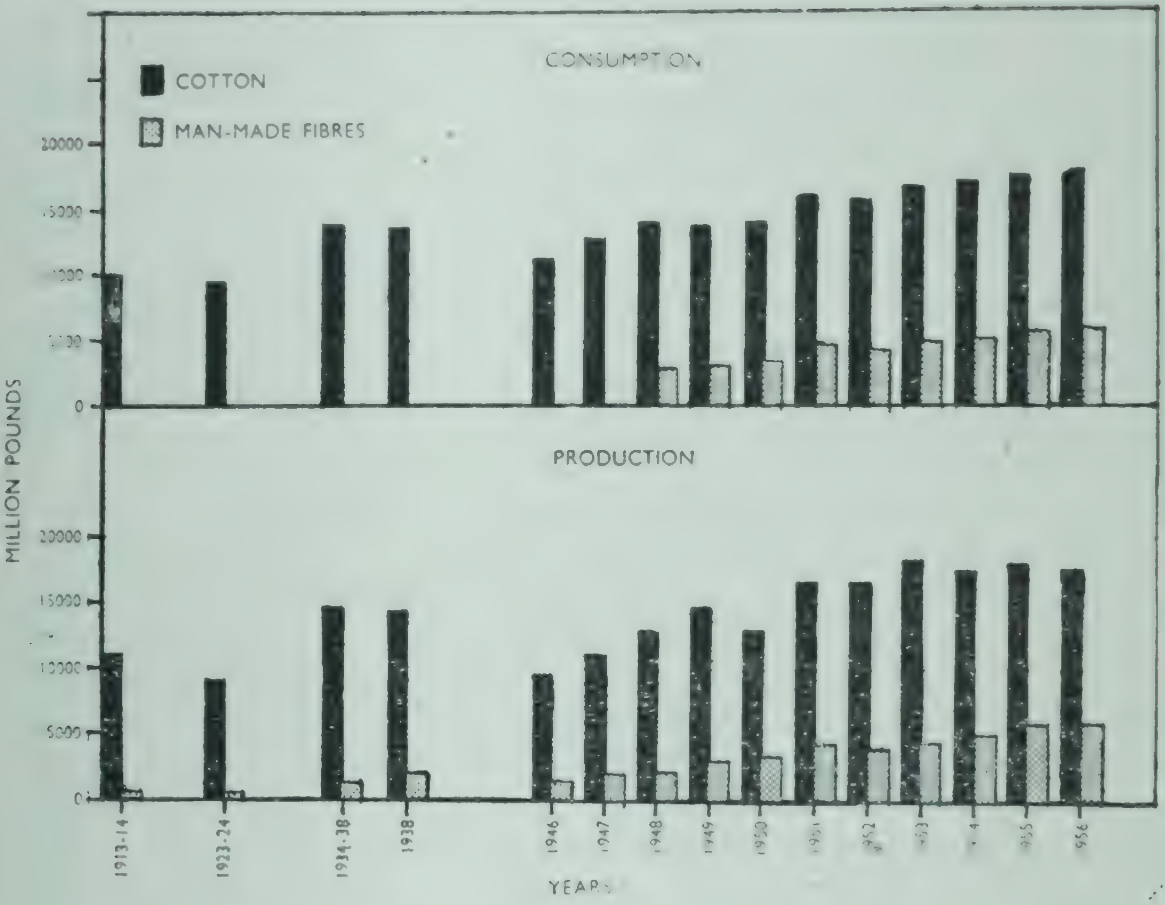

Fig. 32. World Production and Consumption of Cotton and Man-Made Fibres

TABLE 47. PRODUCTION AND CONSUMPTION OF COTTON AND MAN-MADE FIBRES IN THE WORLD (million pounds)

Year	Cotton		Man-made fibres	
	Production	Consumption	Production	Consumption
1910	9,500		18	Not available
1913-14	10,769	10,011	20	do.
1923-24	9,099	9,551	139	do.
1934-38	14,551	14,130	1,302	do.
1938	14,289	13,640	1,921	1,927
1946	9,630	11,076	1,687	Not available
1947	11,115	12,373	1,988	do.
1948	13,055	13,827	2,451	2,444
1949	14,330	13,625	2,704	2,697
1950	12,839	14,069	3,634	3,634
1951	16,446	16,086	4,197	4,222
1952	16,521	15,805	3,805	3,830
1953	17,992	16,533	4,487	4,466
1954	17,819	17,178	4,923	4,893
1955	18,184	17,486	5,611	5,568
1956	17,838	17,820	5,929	5,720

western countries to raise the capacity of the man-made fibres. The success of a textile fibre depends upon low cost of production, ease of processing on available machinery, the demand for its manufactured goods and the amount of research spent on improving it. The data regarding the cost per pound of some important textile fibres are given in Table 48.

TABLE 48. AVERAGE COST PER POUND OF SOME IMPORTANT TEXTILE FIBRES (cent.)

Year	Indian cotton	American cotton	Viscose staple fibres	Wool (territory)	Silk	Nylon	Dacron or Terylene
1939	6·9	9·3	25·0	82·8	271·3	..	..
1945	12·7	22·6	25·0	117·7	..	..	..
1946	13·2	30·6	25·4	102·6	..	..	..
1947	13·3	34·4	31·9	123·2	455·0	..	..
1948	16·8	33·8	36·4	164·6	260·0	..	..
1949	18·2	31·6	35·8	166·4	300·0	..	..
1950	18·4	36·2	36·1	199·2	346·5	..	..
1951	22·9	41·4	40·0	270·5	483·3	..	..
1952	24·4	38·8	39·5	165·3	509·6	..	..
1953	20·5	32·9	35·0	172·9	539·5	175	225
1954	19·8	34·1	34·0	170·6	492·0	175	160
1955	17·6	34·9	33·7	142·1	459·4	150	160
1956	20·5	34·8	32·0	137·1	448·6	130	152

It will be noted that the cost of cotton in India is much lower than that in America, which is nearly the same as that of viscose staple. The cost of wool, silk, nylon and other fibres is much higher. Thus, although the cost of viscose is as low as that of American cotton, it is still very much higher than that of Indian cotton. Indian cotton need not, therefore, be afraid of any severe competition in the near future even from rayon, the production of which has been increasing fast (Fig. 33).

However, there is no room for complacency, as further researches may lead to cheaper methods of production of rayon. Marginal cotton production may not be able to withstand competition. Unless the yield per acre is increased and the quality of cotton is improved, serious difficulties may be encountered in future. However, there is no need for undue despondency either. As was recently pointed out by Dr. Turner,* limitations of total available land on earth, and the demand for more food place a ceiling for the production of natural fibres. Further, the population of the world is increasing; so also is the standard of living. Consequently there would be much greater demand for textiles and in order to meet them, the natural fibres have

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* Address to the members of the Textile Institute, Bombay Branch, March, 1958.

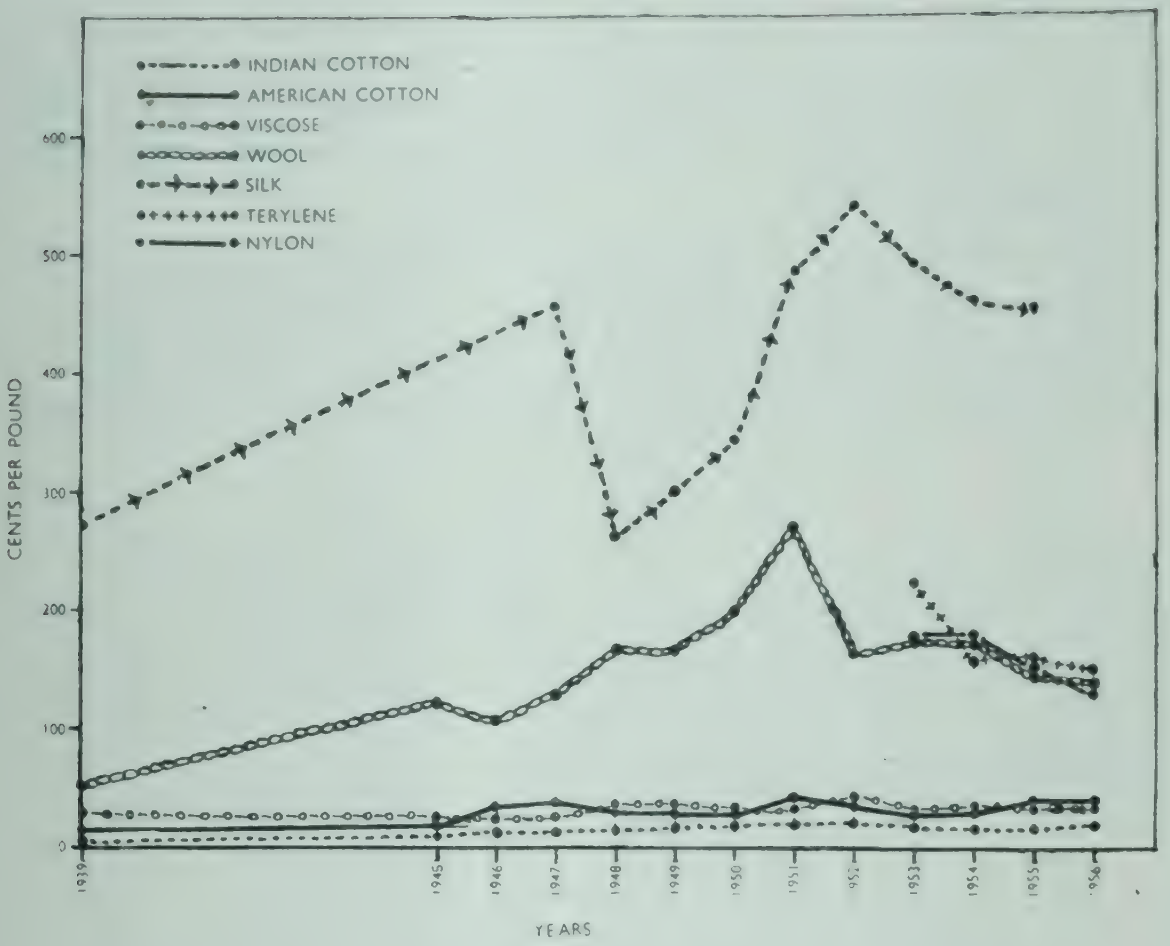

Fig. 33. Average Cost per Pound of Some Important Textiles Fibres

necessarily to be supplemented by man-made fibres, which are, in consequence, not rivals but complementary to cotton. The new man-made fibres are particularly suitable for specialised uses and, therefore, may help to release more cotton for apparel fabrics than before.

PRESENT POSITION AND FUTURE PROSPECTS

The growth and progress of cotton cultivation and textile industry in India has synchronised with the growth of Indian nationalism itself. A welcome feature of the cotton economy of the country, since independence, is the success achieved in off-setting the effects of partition on cotton production in India. Immediately after partition, India had to depend on foreign countries for about 38 per cent. of her annual requirements. That this dependence was largely overcome within a span of seven to eight years is no mean achievement and the credit for this must go to the Indian Central Cotton Committee, its Technological Laboratory and the Departments of Agriculture of different cotton growing States. The process necessitated the entire replacement of the traditional short staples of *desi* cottons by superior long staple varieties.

Commencing its career in a very unimpressive manner in 1856, the textile industry passed through neglect, grudging support and sometimes even opposition from an alien government, until it emerged as the second of its kind in the world and the first organised industry in India. It is interesting to note here that the capital investment in the industry aggregated rupees 203 crores in 1951. The daily average number of workers in the mills in 1955 was 7,58,043. The mills continue to provide indirect employment on a vast scale in the shape of work for handlooms, powerlooms and dealers in stores and cotton goods.

Another significant aspect of the Indian textile industry is the emergence of India as a textile exporting country. It has been shown in Table 46, that the export of cloth from India was 161 million yards in 1923-24, rising to 680 million yards in 1955-56. It may be mentioned that the export of piece-goods, mill and handloom, from India in 1955 constituted 19 per cent. of the total export from 10 main supplying countries. Side by side with the increase in exports, the imports of cotton piece-goods have been subtantially reduced, the actual figures being 1,420 million yards in 1923-24 against only three million yards in 1955-56.

A factor which indicates that the outlook for the industry is brighter at present than at any time in the past, is the upward trend in the *per capita* consumption of cloth. The *per capita* availability, which may be used as a rough index of *per capita* consumption has been steadily increasing from year to year as was pointed out earlier. It was 9.7 yards in 1950-51 but in the following years, it moved up and stood at 16.5 yards in 1955-56. The implementation of the Second Five-Year Plan is bound to raise the living standards of the people and with such increase must come a higher demand for cloth. The initial increments in the income, which accrue through economic development, are generally spent on food and cloth in all under-developed countries. Applying this criterion to India, a significant rise in the *per capita* consumption of cloth may be expected. Indeed, the Planning Commission has placed such consumption at 18.5 yards in 1960-61, the last year of the Second Five-Year Plan.

Even this estimate of 18.5 yards is a very modest one when compared to the *per capita* consumption of 64 yards in the United States, 36 in Sweden, 35 in the United Kingdom and 21 in Japan. However, prospects of an increase in the *per capita* consumption of cloth is both an opportunity and a challenge to India's textile industry. The upward trend in the *per capita* consumption should be harnessed to the good of all sections of the industry. This underlines the need for wise and continuous adjustment in textile policy. Taking the above *per capita* consumption and the increase in population into consideration, the country will have to produce annually 8,400 million yards of cloth by 1960-61. The present production of cloth by all the three sectors, i.e., mills, powerlooms and handlooms, is about 6,700 million yards a year. Therefore, an additional quantity of 1,700 million yards of cloth is required. To achieve this increased production, the textile industry will have to expand by about 25 per cent. of its present size and invest about rupees 100 crores during the next few years.

After careful consideration of the increased textile production, the Government of India has fixed the target of cotton production at 6.5 million bales by 1960-61. This would require, on the basis of the current average yields, an area of about 26 million acres. But the extension of cotton acreage would seriously interfere with the country's programme for increasing food production. However, the various river valley projects after completion are expected to bring under irrigation 4.5 million acres of land, of which roughly 1.5 million acres may be used for the cultivation of good quality cotton. Under these conditions, emphasis had to be laid on increasing the yield per acre by intensive scientific cultivation methods.

However, the industry would have to depend, for its consumption of cottons of 1-1/16″ and above, on imports from foreign countries for some more years to come. For their supply, the country has been spending a colossal amount of some Rs. 50 crores. An analysis of imports during 1955-56 shows that it consisted of 0.26 million bales of 1-1/16″ to 1-1/8″ staple, valued at Rs. 20 crores and 0.35 million bales of 1-3/16″ and above, valued at Rs. 32 crores.

In this connection, it is encouraging to note the healthy trend in the mill consumption of cotton during recent years. In 1955-56, the mill consumption of Indian cotton was 4.37 million bales, against 0.60 million bales of foreign cotton, whereas in 1950-51, it was 2.52 and 1.10 million bales, respectively. This amounts to an increase of 73 per cent. in the consumption of Indian cotton with a decrease of 46 per cent., in that of foreign cotton. This was rendered possible by the improvement in the quality of Indian cotton, in general, and the production of varieties, similar to those imported, in particular. Commendable work has been done in the States of Bombay, Madras and the Punjab, where varieties, such as 170-Co.2, 134-Co. 2-M, M.C.U.2 and L.L. strains, which possess a staple length of 1-1/16″ and above and comparable to imported American and the East African varieties, have been evolved. The immediate efforts of the Indian Central Cotton Committee are directed towards increasing their production, besides maintaining and making further improvement in their quality. There is thus a good scope for production of substantial amounts of cottons of these varieties.

Efforts are also being made for growing cottons of staple 1-3/16″ and above on the West Coast of Kerala and Mysore States. With the introduction of 'Andrews' variety of Sea Island cotton, it has been possible to obtain high yields of extra superior quality cotton in these regions. Yields of over 1,000 lb. per acre and spinning quality of 70 to 80 counts, similar to the imported Egyptian-Karnak, have been obtained. A large scope exists for expanding the cultivation of this cotton in these regions. It is hoped that during the course of the next few years, its cultivation would be extended to several thousands of acres, producing many thousands of bales. Then it may be possible to reduce the imports of such cottons to some extent thereby saving the country several crores of rupees by way of the foreign exhcange.

It will be seen from the foregoing account that resources are available for the production of adequate quantities of cotton in the country to meet the expanding requirements of the indigenous textile industry, except for some portion in the realm of extra-long staple cottons. It is expected that the agricultural and economic policies of the Government will be so shaped as to make the modest targets under the Second Five-Year Plan capable of achievement. It is further hoped that during the Third and Fourth Plans, efforts will be made to cover the gap in the production of extra-long staple cottons, so that India will achieve self-sufficiency in her requirements of cotton in the near future.

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I.C.C.C.=Indian Central Cotton Committee.
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CHAPTER VI

LEGISLATIVE MEASURES

INTRODUCTION

Cotton is one of the most important agricultural commodities of India. It is perhaps the country's foremost cash crop. As such, its cultivation, primary processing, marketing and industrial utilisation have received great attention from growers, merchants, manufacturers, government and law-makers. It has been rightly said that "many of the important changes in India's economy owe their birth to raw cotton problems."

Cotton being the raw material used mostly for the manufacture of yarn and cloth, it is necessary to grow such qualities and market them in such a manner as will, on the one hand, eminently satisfy the requirements of the cotton spinner and consumer of cloth and, on the other, prove profitable to the grower.

So long as cotton was grown largely for domestic consumption or the cloth requirements of the village, its production and handling were not beset with any serious problems other than those connected with the vagaries of season and the hazards of pests and plant diseases. The latter were seldom recognised in their true import or seriousness and tackled properly or with vigour. With the rapid expansion of cotton-growing, first to supply the required raw material to the British textile industry and then to meet the needs of Indian mills, numerous important problems relating to cultivation, processing and marketing cropped up. The principal ones that demanded attention from time to time may be enumerated as follows :

1. A large number of varieties differing greatly in spinning quality and, hence in market price, came under cultivation often in adjoining tracts and sometimes in the same locality.
2. In its march from the field to the factory, the raw produce began to be handled by a large number of intermediaries, such as money lenders, village traders, itinerant buyers, city merchants, ginning and pressing factories and dealers in terminal markets. These different functionaries had conflicting interests and were often not very particular about either marketing the produce unadulterated or giving the farmer a fair deal.
3. Most of the cotton markets were ill-organised, weights not uniform, trade allowances, discounts and other practices unregulated,

storage arrangement unsatisfactory and market intelligence almost non-existent.

4. The growing of the crop was taken up by a vast number of ill-informed cultivators of poor means and small holdings. Most of them were either not particular or not in possession of the knowledge or the means to use the best seed, adopt improved cultivation practices or to market the produce clean and unmixed.
5. With the advent of the machine ginning industry and the system of the peasants selling their produce in the form of *kapas* (unginned cotton), the cultivators gave up retaining their own sowing seed and took to planting gin-run, non-descript, mixed seed of inferior quality.
6. The extension of cultivation to new areas and the growing of the crop practically throughout the year in southern India enhanced the incidence of diseases and pests. The import of large quantities of superior foreign cotton increased this hazard still further.

The multiplicity of varieties differing in price led to their fraudulent mixing by some sections of the trade, ginning factories and farmers with the consequent deterioration of seed. Similarly, the large increase in the number of intermediaries handling cotton and the abuse of marketing processes to which they resorted, robbed the cultivator of his just dues. The increase of pest and disease hazards lowered crop yields and seriously cut the profits of cotton growing. For the effective prevention of malpractices and the solution of other problems, legislative action was taken by the Government from time to time. The Acts legislated fall into the following five categories :

1. Prevention of admixture and other malpractices.
2. Maintenance of purity of improved varieties in the field.
3. Provision of better marketing and storage facilities.
4. Collection of cotton statistics.
5. Control of pests and diseases.

The following paragraphs give a brief account of the principal enactments made or in force.

PREVENTION OF ADMIXTURE AND OTHER MALPRACTICES

Broadly speaking, the evils affecting Indian cotton under this head fall into the following four categories.

1. Mixing of different varieties of cotton.
2. Watering of cotton.
3. Mixing of foreign substances like cotton seed, cotton waste, jute and hemp fibres, ropes, sand, small stones, grease, oil, etc.
4. Bad ginning, resulting in a high percentage of seed cotton getting mixed in lint.

Mixing of different varieties of cotton is, to some extent, due to many small cultivators selling their *kapas* produce to village shop-keepers or money lenders, who bulk these small lots for sale to bigger dealers or ginners purchasing cotton. These intermediaries in their turn mix their purchases for large-scale ginning and pressing before sale to textile mills or exporting firms. Besides this type of mixing, the cultivators at times mix the produce of different varieties either because the sale of mixed cotton is more profitable or because the separate marketing of superior types is not adequately recompensed by the trade. However, the mixing practised by the cultivators or the village merchants is not so grave as that current in the ginning factories. These factories mix inferior or short staple cotton with superior or long and medium staple varieties with a view to passing off the inferior cotton at the price of the superior produce. Sometimes short staple cotton is transported long distances to the tracts growing superior cottons, for purposes of fraudulent mixing.

Watering of lint before pressing in order to increase its weight is yet another evil. It is claimed in its justification that watering softens, strengthens and lengthens the staple and makes the pressing easier. It is, however, difficult to draw a line between useful moistening and watering with fraudulent motives. The legitimate objective, if any, can be served by merely stacking lint on a slightly damp floor for a short time before pressing.

Foreign substances found mixed with cotton lint include cotton waste, cotton seed, *kapas* and other substances like broken leaves, earth, pieces of twine and rope, oil matting, pieces of cloth, etc. Formerly, huge quantities of cotton waste and cotton fly used to be despatched by rail and road from mill centres like Bombay to pressing centres and utilised for the purpose of mixing. Mixing of cotton seed or *kapas* may be due either to deliberate adjusting of the ginning machinery to permit cut or crushed seed to pass into ginned cotton, or to placing of seed or unginned cotton in the middle of ginned cotton while pressing (i.e., false packing). The presence of other foreign matter is mainly the result of faulty conditions of handling and storage prevailing in the factories.

Bombay Regulation (1829) and Amending Acts. Complaints relating to the mixing of different varieties of cotton in the process of ginning and pressing and to frauds in packing and sale of produce started ever since the exports of Indian cotton assumed a sizable proportion in the early years of the 19th century. The British Government in India, in its anxiety to supply the English textile industry with good clean cotton of standard purity, made the mixing of different varieties of cotton a penal offence. In 1829, the Government of Bombay enacted a regulation to check frauds committed in the packing and sale of cotton. The penal clause of this regulation provided that "any person fraudulently mixing good and bad descriptions of cotton in one bale and fraudulently offering for sale or selling cotton so packed as good cotton, and any person fraudulently deteriorating cotton by exposing it by night to heavy dews, by putting dirt, stones, earth or any other substance or salt water amongst it, with a view to making it heavier, shall be punished with fine and imprisonment, for the first offence, not exceeding two years and conviction of a second or more offences with fine and imprisonment not exceeding seven years." It further stipulated that "cotton so fraudulently offered for sale and sold, shall be liable to confiscation, and to be burnt or otherwise destroyed." Several prosecutions were launched by the government but inspite of the heavy punishments provided in the Regulation, the results were not encouraging and complaints regarding deterioration continued unabated. For the better suppression of frauds in respect of cotton in Bombay, an Act was, therefore, passed in 1851. This Act repeated most of the provisions of the 1829 Regulation with minor alterations but added some clauses introducing a system of paid informers. In 1863, as a result of the enquiries of a Commission on the subject, the Government of Bombay passed a more comprehensive Act which not only penalised fraudulent adulteration and deterioration of cotton and the fraudulent sale or offer for sale of adulterated or deteriorated cotton but also prescribed a penalty for the offer of adulterated cotton for pressing. Furthermore, it required that all cotton presses should be licensed, that every licensee of a press should use a distinguishing name and mark, and that any failure to comply with the provisions of the Act in these respects should be punished with fine. This Act also provided for the appointment of Inspectors of cotton who were given powers of access at all times to ginning and pressing factories and to seize and detain all cotton in respect of which any offence under the Act appeared cognizable. The cost of the establishment thus created was to be met by a fee of annas four levied on every bale of cotton exported from any port or place in Bombay Presidency to any port or place outside British India. This fee was reduced to annas three per bale in 1865 and to annas two in 1872. The Act, particularly the clauses providing for the appointment of Inspectors and the levy of export tax, aroused strong opposition amongst mercantile bodies and other cotton interests. As a result, another Act was passed in 1878. The most important change in the new Act was the abolition of all personal penalties, i.e., imprisonment and fine. The provisions regarding the licensing of presses and the use of press marks, which were not objected to, remained unaltered. The Act, however, found no better favour from the mercantile community and had consequently to be repealed in 1881.

Cotton Transport Act (1923). In 1917, the Government of India appointed an Indian Cotton Committee to inquire *inter alia* into the possibilities of improving the existing methods of ginning and marketing and also of preventing adulteration and damping of cotton. This Committee, after examining voluminous evidence of the problem, made the following recommendations :

1. The transport of cotton waste or fly by rail or sea, except from one

mill to another or to a port for shipment outside India, should be totally prohibited.

2. The transport of loose *kapas* or lint in *dokras* or of half-pressed or full-pressed bales by rail, except to *bona fide* consumers and to ports for disposal there or shipment outside India, should also be prohibited, except in certain cases under licence.
3. All ginning and pressing factories should be licensed, a preliminary to the issue of licences being the assignment to all factories of distinctive numbers and marks which would enable the cotton dealt with by them to be traced.
4. Licences should only be granted on certain conditions and should be withdrawn for breach of these conditions and on proof of such malpractices as damping, mixing and adulteration.
5. All ginning and pressing factories should be brought under the operation of the Factory Act and required to take out licences, irrespective of the number of hands employed.
6. Licences should be withdrawn by the Local Government on the recommendation of the Central Committee, after the procedure laid down has been followed.
7. Suitable penalties should be imposed in the case of factories working without taking out a licence or after a licence has been withdrawn.

The Indian Cotton Committee also recommended the formation of an all-India organisation to look after the problems concerning the growing and marketing of cotton. The Indian Central Cotton Committee, thus constituted by the Government of India in 1921 in accordance with this recommendation, has since its inception, devoted its attention to the problem of preventing the mixing, watering and adulteration of cotton.

In order to prevent the influx of inferior cotton, cotton seed and cotton waste and fly into areas growing superior cotton, and thus maintain the quality and reputation of the latter, the Government of India passed the Cotton Transport Act, in 1923. This act empowered the State Governments to prohibit the import of cotton, cotton waste, *kapas* and cotton seed, by rail, road, river and sea into specified areas, unless required for a special purpose and covered by a licence. Major cotton growing States like Bombay, Madhya Pradesh, Madras and Andhra Pradesh issued notifications under this Act, declaring their main cotton growing areas as 'Protected'. The question of applying this Act to the States of Punjab, Uttar Pradesh, Rajasthan and Mysore is under consideration of the respective State Governments. The former State of Hyderabad passed the Hyderabad Cotton Cultivation and Transport Act, 1337F, and declared protected areas under it. This Act is applicable in the concerned areas even after re-organisation of the State.

Cotton Ginning and Pressing Factories Act, 1925. Whilst the prohibition of transport of cotton under the Cotton Transport Act stops the imports of cotton into a tract for mixing purposes, it does not stop mixing of different varieties which are grown side by side in the same tract. To stop this evil, the Government of India passed the Cotton Ginning and Pressing Factories Act in 1925. Section 3 of the Act makes it obligatory on the owner of every cotton ginning and pressing factory to maintain a register containing a record of all cotton ginned and pressed in the factory and of the names of persons for whom the cotton was ginned and pressed. Section 4 of the Act provides for marking, in the prescribed manner, every bale pressed in the factory, with a serial number and with the mark assigned to the factory. This system enables a bale to be traced to its source and serves as a check on malpractices at the factories. In order to deal with the abuses which arise out of the faulty conditions obtaining in the ginning and pressing factories, the Act requires compulsory compliance with certain structural requirements. However, the system of licensing of cotton pressing factories did not find a place in this Act. Nor did the Act expressly prohibit or penalise the mixing, the watering and the adulteration of cotton. Nevrtheless, these evils continued unabated.

In 1936, the Governments of Bombay and the farmer Madhya Pradesh removed these serious lacunae by amending the Central Act in its application to the respective States, making the licensing of ginning and pressing factories obligatory and prohibiting the watering and mixing of cotton in specified areas under the Act. Since then, all the other major cotton-growing States have amended the Central Act on the lines of the Bombay Act. The statement below shows the position in the various States regarding the passing of the Amendment Acts and their enforcement by framing the necessary rules:

The Punjab Government have repealed the Cotton Ginning and Pressing Factories Act, 1925 in its application to the State and have passed the Punjab Cotton Ginning and Pressing Factories Act, 1953, and framed rules thereunder incorporating the main provisions of the Central Act and Rules and of the State Amendment Acts and Rules in other States.

States that have passed the Amendment Acts	States that have not passed the Amendment Acts
Bombay Madhya Pradesh Madras Andhra Pradesh Uttar Pradesh Rajasthan Punjab Mysore (Belgaum & Raichar Regions)	Mysore (old Mysore region) (A consolidated Bill to amend the Act in its application to the re-organised State is under consideration)

States that have framed the necessary Rules	States that have not framed the necessary Rules
Bombay (except Marathwada and Kutch district)	Andhra Pradesh (Telangana region)
Madhya Pradesh (Mahakoshal region)	Madhya Pradesh (Madhya Bharat and Bhopal regions)
Andhra Pradesh (Andhra Region)	Bombay (Marathwada and Kutch)
Mysore (Belgaum region)	Rajasthan
Punjab	Mysore (Raichur)
Madras	Uttar Pradesh

MAINTENANCE OF PURITY OF VARIETIES IN FIELD

Cotton Control Act. Much of the mixing of foreign substances and the admixture of different varieties of cotton is prevented by the working of the Cotton Transport and the Cotton Ginning and Pressing Factories Acts. For prevention of mixture in the field and in premises other than cotton ginning and pressing factories, supplementary legislation has been found necessary. Accordingly, the Governments of Bombay and Madhya Pradesh have passed the Cotton Control Acts, which prohibit the cultivation of any variety or varieties of cotton, the mixing of one variety of cotton with another and the possession or use of or trade in the prohibited varieties in any part of the States to which the Act is applied. Under the Act, 'Controlled Areas' have been set up for growing only specified varieties of cotton. In the Punjab, the same object is achieved by the Punjab Improved Seed and Seedlings Act, which requires the compulsory planting of pure seeds and seedlings of improved varieties of crops approved and recommended by the State Department of Agriculture. The movement of seeds and seedlings from one area to another is prohibited or regulated by the Act. The improved seeds and seedlings are required to be made available by the Department of Agriculture. Under this Act, the former Punjab State was divided into separate zones for growing specified varieties of American cotton and the growing of *desi* cotton was restricted to the sub-montane districts of Ambala, Hoshiarpur and Gurdaspur. The enforcement of the Cotton Transport Act to prevent the mixing of American and *desi* cottons is under the consideration of the Punjab Government. In the former State of Hyderabad, the object of the Cotton Control Act was served by notifying areas under the Hyderabad Cotton Cultivation and Transport Act (1337F). Figure 34 shows the location of the protected areas constituted under the Cotton Transport, the Cotton Control, the Hyderabad Cotton Cultivation and Transport and the Punjab Improved Seed and Seedlings Acts.

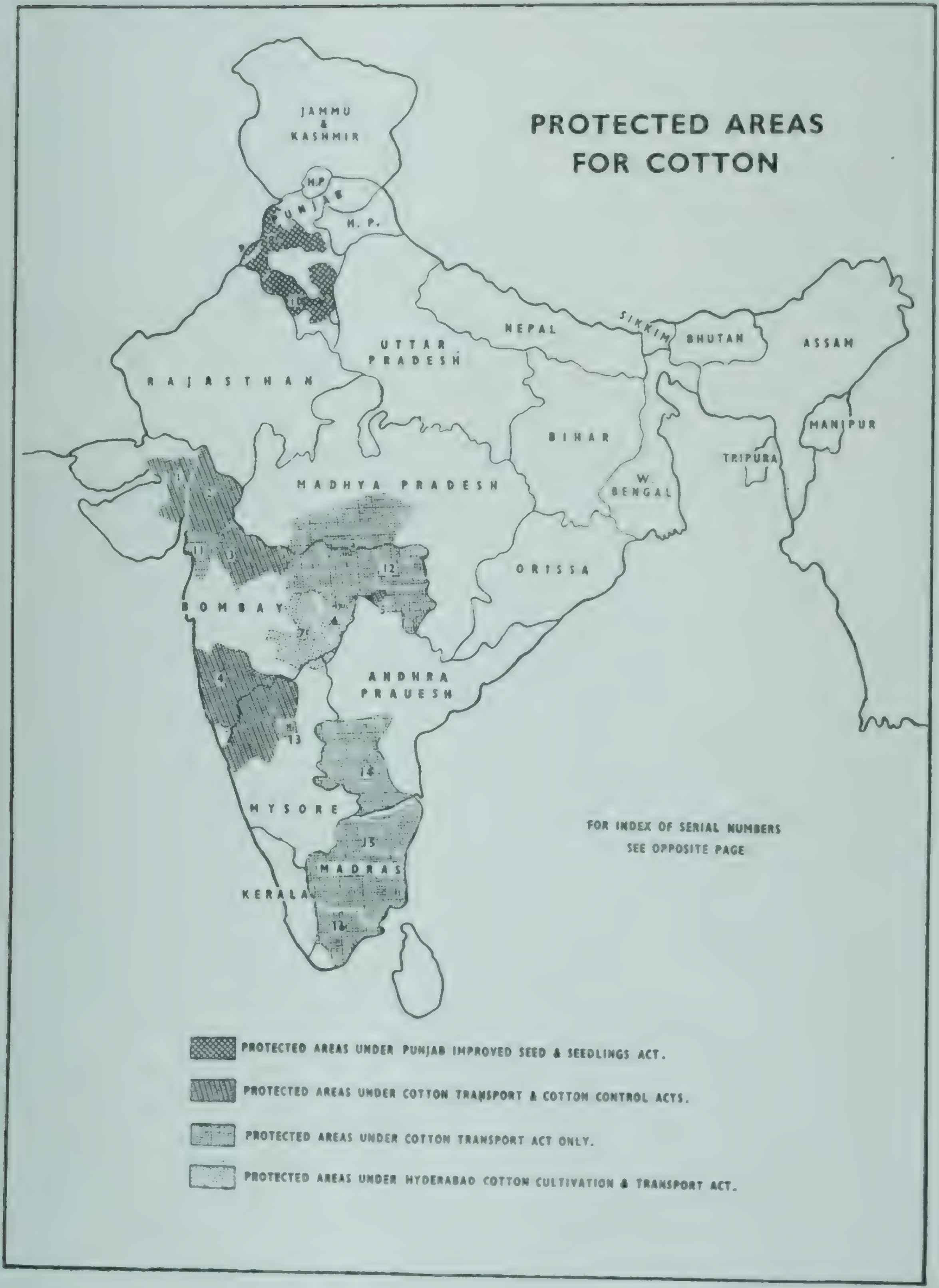
PROTECTED AREAS FOR COTTON
JAMMU & KASHMIR
H.P.
PUNJAB
H. P.
RAJASTHAN
UTTAR PRADESH
NEPAL
SIKKIM
BHUTAN
ASSAM
MANIPUR
TRIPURA
BIHAR
W. BENGAL
MADHYA PRADESH
ORISSA
BOMBAY
ANDHRA PRAUESH
MYSORE
MADRAS
KERALA
11
12
13
14
15
16
FOR INDEX OF SERIAL NUMBERS SEE OPPOSITE PAGE
PROTECTED AREAS UNDER PUNJAB IMPROVED SEED & SEEDLINGS ACT.
PROTECTED AREAS UNDER COTTON TRANSPORT & COTTON CONTROL ACTS.
PROTECTED AREAS UNDER COTTON TRANSPORT ACT ONLY.
PROTECTED AREAS UNDER HYDERABAD COTTON CULTIVATION & TRANSPORT ACT.

Fig. 34. Protected Areas for Cotton

Protected Areas for Cotton

Serial number in map on opposite page	Name of tract	Districts included	Standard variety	Area under cotton (*thousand acres*)
A. PROTECTED AREAS UNDER COTTON TRANSPORT AND COTTON CONTROL ACTS				
1.	North Gujerat	Mehsana district and part of Ahmedabad district of Bombay State.	Kalyan	713
2.	Middle Gujerat	Sabarkantha, Kaira, Panch Mahals, Baroda districts and parts of Ahmedabad and Broach districts of Bombay State.	Vijay	1,485
3.	Khandesh	East & West Khandesh districts & part of Nasik district of Bombay State.	Virnar	748
4.	Kumpta-Dharwar & Bijapur-Bagalkot	Ratnagiri, North & South Satara, Kolhapur districts & part of Sholapur district of Bombay State ; Belgaum, Bijapur, North Kanara & Dharwar districts of Mysore State.	Jayadhar Laxmi & Virnar	1,442
5.	Vidarbha	Pusla & Jarud Revenue circles of Amraoti district and Wani-Welabai and Sakra-Moregaon circles of Yeotmal district of Bombay State.	H. 420 & Buri 0394	150
B. PROTECTED AREAS UNDER HYDERABAD COTTON CULTIVATION & TRANSPORT ACT				
6.	Marathwada	Nanded dtistrict & part of Parbhani district of Bombay State, Nirmal *taluka* of Adilabad district of Andhra Pradesh.	Gaorani 6	1,027
7.	,,	Osmanabad district and parts of Bhir & Parbhani districts of Bombay State ; Part of Medak district of Andhra Pradesh & Bidar district of Mysore State.	Gaorani 12	
C. PROTECTED AREAS UNDER PUNJAB IMPROVED SEED & SEEDLINGS ACT				
8.	Sub-montane tract	Amritsar, Jullundur & Ludhiana districts & parts of Ferozepur, Gurdaspur, Bhatinda and Hissar districts of Punjab.	Punjab American 320F	563
9.	L. S. S. tract	Fazilka & Muktsar tehsils of Ferozepur district of Punjab	Punjab American L.S.S.	105
10.	Hariana tract	Rohtak & Karnal districts & parts of Hissar & Bhatinda districts of Punjab.	Punjab American 216F	186

D. PROTECTED AREAS UNDER COTTON TRANSPORT ACT ONLY

11.	South Gujerat	Surat district and parts of Broach & West Khandesh districts of Bombay State.	705
12.	Vidarbha & M. P. Area	Buldana, Akola, Amravati, Yeotmal, Wardha, Nagpur Bhandara & Chanda districts of Bombay State ; Nimar, Hoshangabad & Chhindwara districts of Madhya Pradesh State.	3,956
13.	Raichur Area	Eastern *talukas* of Raichur district of Mysore State.	100
14.	Northerns and Westerns Area	Kurnool, Anantapur, Chittoor and Cuddapah districts of Andhra Pradesh.	647
15.	Cambodia Area	Chingleput, South & North Arcot, Salem, Coimbatore, Tiruchirapalli, Tanjore and parts of Madura and Ramnad districts of Madras State.	1,123
16.	Tirunelveli Area	Tirunelveli district and parts of Madura and Ramnad districts of Madras State.	

Agricultural Produce (Grading and Marketing) Act, 1937. This Act was passed by the Government of India in 1937. It provides for the grading and marking of agricultural and other produce. By notification under this Act, the Central Government apply its provisions to any agricultural produce or other articles. Specified varieties of the articles produced in particular areas, and included in the schedule of the Act are given a special mark, the unauthorised use of which is made illegal. In March, 1939, the Government of India notified that this Act would be applicable to cotton. Specified varieties in some States are now, therefore, marketed under a distinguishing 'Agmark' as a guarantee of purity. In 1955-56, agmarking of cotton bales was in force in Khandesh, Surat, Middle Gujerat and Bombay-Karnatak tracts of the former Bombay State.

REGULATED MARKETING AND IMPROVED STORAGE

Legislative measures for the improvement of marketing of cotton and regulation of trade allowances, etc., have been taken by the Government of India and the State Governments. Agricultural Produce Markets Act, Agricultural Produce (Development and Warehousing) Corporations Act, Forward Contracts (Regulation) Act, Essential Commodities Act, etc., come under this category. These Acts are comprehensive in nature and cover many agricultural commodities besides cotton.

Agricultural Produce Markets Act. Due to the large number of hands through which cotton passes, the cotton grower seldom receives adequate price for his produce. He would obtain a better price if the number of middlemen was reduced or if he was brought more directly in touch with large buyers or ultimate users. One of the most satisfactory ways in which this can be done is by the establishment of open markets. Such open markets were in existence in Central Provinces and Berar even before the close of the last century. The cotton markets in Berar were established and administered under the Berar Cotton and Grain Markets Law, 1897, and the rules framed under it. The Indian Cotton Committee of 1917 recommended the establishment of cotton markets of the Berar type in other States also. In 1923, the Indian Central Cotton Committee drafted a bill on the Berar model with necessary modifications for general enactment by cotton-growing States. As a result, Agricultural Produce Markets Acts were enacted in the former States of Bombay, Madras, Madhya Pradesh, Punjab, Mysore, Andhra Pradesh, Pepsu, Madhya Bharat and Hyderabad. These Acts provided for the establishment of regulated markets for the better regulation of buying and selling of agricultural produce including cotton. Most of the important cotton markets in the former States of Bombay, Madhya Pradesh, Punjab, Mysore, Hyderabad, Madhya Bharat and Pepsu were brought under the purview of these Acts. A few markets in Madras and Andhra Pradesh were also regulated. The number of regulated markets in different States in 1958-59 was as under :

State	Regulated markets
Bombay	171
Madhya Pradesh	40
Punjab	78
Mysore	75
Madras	18
Andhra Pradesh	18

Many of these markets deal not only in cotton but in other agricultural produce also.

Forward Contracts (Regulation) Act, 1952. In India, Bombay has been the biggest centre for organised trading in cotton ever since 1875, when the first organised association for trade in cotton was started under the name the Bombay Cotton Trade Association. Around 1890, another association called the Bombay Cotton Exchange, Ltd., was established. From 1893 to 1918, these two associations shared between themselves the control of the forward and ready trading in cotton. In 1918, during the First World War, the price of cotton reached such an artificial height that some sections of the trade approached the Government to fix the price of cotton. The Government, however, did not intervene to this extent but framed the 'Cotton Contracts Rules' under the Defence of India Act and appointed a Cotton Contracts Committee to regulate the cotton trade in Bombay. These temporary rules were replaced in 1919 by the Bombay Cotton Contracts Act which was passed by the Government of Bombay. Similarly, the Cotton Contracts Committee was replaced by the Cotton Contracts Board constituted under the new Bombay Act. This legislation, which vested in that Board the control of dealings in cotton in the State of Bombay, was also of a temporary nature and its life was confined to the duration of the War and for such period thereafter, being not less than six months and not exceeding two years, as the Governor may by notification direct. While the Cotton Contracts Board was functioning, the Indian Cotton Committee of 1917 referred in its report to the conditions existing in the Bombay Cotton Market and recommended the formation of one Central Association in place of the seven distinct bodies, which at that time controlled the cotton trade in Bombay. As a result of this recommendation, the Government of India addressed the Government of Bombay in 1920, inviting the Cotton Contracts Board to proceed with the formation of the East India Cotton Association. This new Association came into being on the 1st May, 1922, and the Bombay Cotton Contracts Act was passed by the Bombay Government in the same year empowering the Association to regulate dealings in cotton in Bombay. In June, 1930, the Government of Bombay appointed a Committee known as the 'Wiles-Committee' to examine and report *inter alia* on the working of the Bombay Cotton Contracts Act, 1922, with particular reference to the constitution of the East India Cotton Association. In order to widen the scope of the Act as recommended by the 'Wiles-Committee', the Bombay Cotton Contracts Act, 1932, was enacted, which remained in force up to the 31st March, 1948.

In view of the developments that took place during the Second World War, the Government of Bombay realised the need for greater control of forward trading in cotton and appointed a Committee of the Cabinet in September, 1946, to examine the question. Recommendations made by this Committee led to the enactment of the Bombay Forward Contracts Control Act, 1947. Under this Act, the East India Cotton Association, Ltd., Bombay, was appointed the only body for regulating dealings in forward contracts in cotton in Bombay State. In the Constitution of the Republic of India framed in 1949, the subject of 'Stock Exchanges and Futures Markets' was included in the Union List and, therefore, the enactment of a comprehensive Central Legislation became necessary. Accordingly the Forward Contracts (Regulation) Act was passed by the Government of India in December, 1952.

This Act provides for the regulation of forward trading and the prohibition of 'options'. The regulatory provisions of the Act are extended by notification to different classes of goods and to different areas as and when necessary. The underlying principle is that forward contracts should be made only in accordance with the rules and bye-laws of a recognised Association. The rules and bye-laws of such Associations are subject to the approval of the Central Government, who have also the power to make rules and bye-laws on their own initiative. Furthermore, under the Act, the Central Government has the power to appoint one person as its own representative and not more than three persons to represent interests not directly covered by the membership of the Association, on the governing body of the recognised Association. The Central Government can also order enquiry into the affairs of a recognised Association or those of any of its members and to direct the Forward Markets Commission (established under the Act) to inspect the accounts and other documents of the Association. In an emergency, the Central Government have powers to suspend the business of a recognised Association for a period not exceeding six months, or even to withdraw recognition.

Finally, to assist the Central Government in the administration of the Act, provision has been made for the appointment of a Forward Markets Commission and an Advisory Committee. In conformity with these provisions, a Forward Markets Commission was set up to discharge the functions assigned to it, and the regulation and control of forward and spot trading in cotton was transferred from the Government of Bombay to the Commission as representing the Central Government. At the same time, the East India Cotton Association, Ltd., was granted recognition for forward trading in cotton at Bombay. Subsequently, the Government of India permitted the establishment of forward cotton markets at Akola, Ujjain, Indore and Ahmedabad.

Essential Commodities Act, 1955. During the Second World War, the production of cloth for civilian use had to be cut to essential needs. The resultant shortage of supplies caused a sharp increase in the price of both cloth and raw cotton. The prevention of speculation and undue rise in prices necessitated the levy of controls on the price, production and distribution of these commodities. Accordingly, the Cotton (Forward Contracts and Prohibition) Order and the Cotton Cloth and Yarn (Control) Order were issued in 1943 under the Defence of India Rules, and practically every phase of the activities of the cotton textile industry was brought under official control. Two years later, the Indian Cotton Control Order was issued with the object of fixing the maximum and minimum prices of cotton, *kapas* and cotton seed and regulating the distribution and movement of cotton. After the expiry of the Defence of India Rules, the requisite powers were taken by the Government of India under the Essential Supplies (Temporary Powers) Act, 1946. This temporary Act was replaced in 1955 by the Essential Commodities Act, which is now in force as a permanent measure.

This Act provides for the control of the production, supply, distribution and trading of certain commodities. Section 3 of the Act empowers the Central Government to make statutory orders wherever necessary for the purpose of maintaining or increasing the supply of any essential commodity or for securing its equitable distribution and availability at a fair price, by regulating or prohibiting the production, supply and distribution thereof and trade and commerce therein. Raw cotton, whether ginned or unginned, and cotton seed have been included in the list of essential commodities defined under Section 2 of the Act.

Under Section 3 of the Act, the Government of India issued the Cotton Control Order, 1955, which, *inter alia* empowers the Government to fix the maximum and minimum prices and control the movement and distribution of and trading in cotton, *kapas* and cotton seed. Some of the improved superior varieties of cotton like the Indo-American 170-Co.2, 134-Co.2-M and Madras Cambodia Uganda 1 and 2 were kept outside the price control to encourage their production. Similarly, the Madras Government issued the Superior Cotton Production and Certification Order enabling it to grant certificates of purity for the produce of these superior varieties.

Agricultural Produce (Development and Warehousing) Corporations Act, 1956. This is another piece of legislation which has been passed to assist the cotton grower in the orderly marketing of his produce. It provides for the establishment and regulation of warehouses of agricultural produce on co-operative principles. Raw cotton, whether ginned or unginned, and cotton seed are included in the commodities defined as 'Agricultural Produce' under the Act. The constitution of National Co-operative Development and Warehousing Board and Central and State Warehousing Corporations has been provided in the Act. The functions of the Board are as under:

1. National Co-operative Development and Warehousing Board:
   (*i*) to plan and promote programmes for the production, processing, marketing, storage, warehousing, export and import of agricultural produce through a co-operative society or a warehousing corporation ;
   (*ii*) to advance loans or grant subsidies to the State Governments for financing co-operative societies ;
   (*iii*) to provide funds to a State Government or a warehousing corporation for financing co-operative societies for the purchase of agricultural produce on behalf of the Central Government ;
   (*iv*) to subscribe to the share capital of the Central Warehousing Corporation or advance loans or grant subsidies to that Corporation or any State Warehousing Corporation ; and
   (*v*) to plan and promote programmes through co-operative societies for the supply of seeds, manures, fertilizers, agricultural implements and other articles for the development of agricultural produce.

2. Central and State Warehousing Corporations :

   (*i*) to acquire and build godowns and warehouses at such suitable places in India as it thinks fit ;

   (*ii*) to run warehouses for the storage of agricultural produce, seeds, manures, fertilizers and agricultural implements offered by individuals, co-operative societies and other institutions ;

   (*iii*) to arrange facilities for the transport of agricultural produce to and from warehouses ;

   (*iv*) to subscribe to the share capital of a State Warehousing Corporation ;

   (*v*) to act as agent of the Board or of the Government for the purposes of the purchase, sale, storage and distribution of agricultural produce, seeds, manures, fertilizers and agricultural implements ; and

   (*vi*) to carry out such other functions as may be prescribed.

The most important advantage that the agriculturists will derive from the establishment of the warehouses all over the country, is the creation of warehouse receipts which can serve as a collateral security for the provision of credit to them. This facility would help in eliminating distress sales by the cultivator at harvest time, when the prices are generally low due to heavy arrivals. At the same time the consumer will be assured of a regular flow of the commodity to the market on a more or less even price throughout the year. Further, the storage of the commodity in warehouses constructed on scientific lines and looked after by expert technicians will eliminate large losses through insect pests, rats, etc. Another advantage of the legislation is the smooth trading resulting from the grading of the produce to be stored in the warehouses. Grading according to recognised standards will make it unnecessary to check the commodities physically or to trade in them by samples.

COLLECTION OF STATISTICS

For a correct assessment of the supplies of cotton available during each season and for the verification of the accuracy of the annual estimates of the cotton crop, it is essential to have an exact idea of the cotton stocks carried over from one season to another. Stocks of cotton held by the trade and the mills at the end of each month are collected by the Textile Commissioner, Bombay, under the Cotton Control Order, 1955. In view of the importance of complete information regarding the end-season stocks of different varieties of cotton held by the trade, cotton ginning and pressing factories, etc., the Governments of Bombay, Madhya Pradesh, Uttar Pradesh and the Punjab have passed the Cotton Statistics Acts, which provide for the collection of figures of stocks as on the 31st August each year.

For the collection of statistics of cotton actually pressed every year, use is made of the Cotton Ginning and Pressing Factories Act, 1923. Under this Act, all cotton presses in the country are required to submit weekly returns of the cotton pressed. Similarly under the Essential Commodities Act, 1955, the Textile Commissioner obtains and publishes, fortnightly and monthly, statistics pertaining to the stocks of different varieties of Indian and foreign cotton held by the trade, or held or consumed by the manufacturers.

CONTROL OF PESTS AND DISEASES

Destructive Insect and Pests Act, 1914. This Act provides for the prohibition or regulation of the import into India of any article or class of articles likely to cause infection to any crop. To prevent introduction of foreign pests of cotton, the imports of *kapas* (unginned cotton) have been entirely prohibited under the Act, since 1925. Similarly, to prevent the entry of the most serious of all cotton pests namely the Mexican cotton boll-weevil (*Anthonomous grandis*), the Government of India issued, in 1925, a notification under this Act restricting the imports of American cotton lint to the single port of Bombay and making them subject to compulsory fumigation with hydrocyanic acid gas. Since 1950, imports of American cotton have also been allowed through the ports of Madras and Cochin subject to fumigation. The imports of cotton seed have been restricted since 1930 to the port of Bombay and allowed only if the seed is required for experimental purposes and is obtained through certain officers authorised by the Government of India. The quantity that may be imported is restricted to 1 cwt. in any one consignment and is subject to examination and fumigation with carbon disulphide, where necessary.

LEGISLATION IN FOREIGN COUNTRIES

UNITED STATES

In the San Jaquoin Valley, California (U.S.A.), the cultivation of cotton is restricted by law to only one variety. This helps to maintain the purity of produce. There are also in force several marketing enactments designed for the producers' benefit. Among these, mention may be made of :

1. The Smith Doxy Act, providing for free classification of cotton and furnishing of information on supply, demand, location, condition and market prices of cotton to producers.
2. The Commodity Exchange Act, which prohibits undesirable practices and transactions, and stipulates that all 'futures' transactions in commodities covered by the Act must be made on an exchange designated as a contract market ; cotton is included among the commodities defined under the Act.
3. The United States Cotton Standards Act, which provides for the

establishment and promotion of the use of official cotton standards in inter-state and foreign commerce.

4. An Act authorising the United States' Secretary of Agriculture to collect and publish statistics of grade and staple length of cotton from time to time and to issue periodical cotton crop reports, ginning reports and reports on the area under cotton.

The Commodity Exchange Act is similar to the Forward Contracts (Regulation) Act, 1952, of India.

EGYPT

In Egypt the mixing of different varieties of cotton is prohibited under Decree Law 51 of 1934. Heavy penalties are imposed for mixing of different varieties, and provision has been made for the appointment of Government Inspectors to supervise the ginneries, pressing establishments and local cotton markets to ensure efficient application of the Law. Every bale of cotton is marked with the name of the variety so that the spinner can be sure of the identity of cotton received. Cotton seized under the Law, bales found without the name mark and the miscellaneous lots allowed as mixing under subsidiary clauses (such as seed crop from brokers' offices) are marked 'mixed'.

Another Act for the maintenance of the purity of cotton in Egypt is the Seed Control Law (Law No. 5 of 1926). Under the provisions of this Law, seed cotton intended to provide sowing seed is not allowed to be ginned without a licence and the ginning has to be done under the supervision of an Inspector of the Ministry of Agriculture, attached to every licensed ginnery. At the commencement of ginning, a specified quantity of seed cotton is required to be run to clear the conveyors, etc., before the seed is collected for sowing. The Inspector takes the sample of seed or seed cotton according to a specified routine for examination in the Ministry's Laboratories. If the seed or seed cotton fails to pass the standard laid down for the year, the certificate of fitness is refused and the seed is rejected for sowing purposes. In 1942-43, an important advance was made by basing acceptance or refusal of seed on the spinning quality of ginned cotton. This procedure, however, applies only to long staple varieties. Samples are received in the form of seed cotton at the Cotton Research Board, and after ginning are subjected to a spinning test in the Test Mill. If the yarn strength falls below the standards fixed for each variety, the seed is rejected for sowing. In this way, all long staple cotton of Egypt is now grown directly from seed, whose lint has passed the spinning standards, lot by lot. As a supplement to this, a 'Dated Seed' system has also been developed, under which all seed lots are dated according to the year of approval from the Ministry of Agriculture and the seed derived from these lots is rejected for sowing after a certain time limit, irrespective of whether its condition is sound or not.

Direct control of crop quality by spinning tests, which certainly is a big advance in controlling and maintaining the standard of purity of a variety, has not been adopted anywhere else.

CONCLUSIONS

The foregoing account shows that the Government of India and the State Governments have taken legislative measures from time to time to maintain the purity of cotton varieties and improve the marketing of the Indian crop. Despite these, complaints regarding the malpractices of watering, mixing and adulteration have not ceased. The primary marketing of the crop also leaves much to be desired although the main cotton-growing States have enacted the Agricultural Produce Markets Act. A scrutiny of the various laws does not show any loopholes in their provisions. The defect lies mainly in the enforcement of these Acts. The Indian Central Cotton Committee has recommended a stricter enforcement of the various enactments and investing the State Directors of Agriculture with the power to issue or withdraw licences to gins and presses. The Committee has also offered to appoint Liaison Officers in the various States for a period of three years to help the Directors of Agriculture in the enforcement of the Acts and in the light of the experience gained by this arrangement, to consider thereafter the question of enforcement through a Central Organisation, if so required. For complete eradication of the evils, it is desirable that the different cotton growing tracts of the country should be divided into compact blocks, to which the Cotton Transport Act, the Cotton Control Act, and the Cotton Ginning and Pressing Factories Act may be applied simultaneously and enforced strictly by appointing adequate staff and by establishing check *nakas* (points), wherever necessary. The ultimate objective should be to form each of these blocks into a one-variety tract. Further, in each of these blocks a sufficient number of seed farms, co-operative societies for distribution of pure seed of improved varieties, and marketing societies for the orderly and regulated marketing of produce should be established. Advantage should also be taken in this connection of the facilities provided under the Agricultural Produce (Development and Warehousing) Corporations Act, 1956, and of the National Development and Warehousing Board and the Central Warehousing Corporation established under it.

CHAPTER VII

EXPORTS AND IMPORTS

EXPORTS

From time immemorial, India has had a flourishing trade in cotton textiles, while the trade in raw cotton was negligible. It was the fame of the Indian calicos, muslin and silk that first attracted the western nations to India. However, the import of cotton textiles into England and some European capitals in the 17th and 18th centuries caused such a drain of wealth to India, that propaganda was started against the use of Indian fabrics. This led to the beginning of the cotton spinning and weaving industry in the West, and the raw cotton required for this new industry was imported from India, which was then the only known producer of the commodity.

The East India Company, which in the early years had encouraged the manufacture of cloth in India, reversed that policy by about the middle of the 18th century and began exporting cotton from India for use by manufacturers in Great Britain. It is said that by 1764 about four million lb. of raw cotton had been exported. Meanwhile, the Industrial Revolution had started in England. The improvements which had taken place in the various kinds of machinery for spinning and weaving, as well as in the arts of bleaching and calico printing, from the first introduction of Arkwright's patent spinning frame in 1769 to the establishment of the factory system in 1785, created an insatiable hunger for raw cotton. Till the end of the 18th century, no source of cotton supplies other than India was known. Imports of cotton into Great Britain increased from an average of 6.7 million lb. per annum during the quinquennium 1776-80 to 56 million lb. in 1800. In 1788, the Court of Directors of the East India Company called upon the Governor-General to give every encouragement to the growth and general improvement of cotton, particularly of the species manufactured into the finer type of yarn which was used for the superior Dacca fabrics. In 1793, the Company sent to India the newly invented Whitney Saw Gin to quicken and improve cotton ginning.

Meanwhile, the growing of cotton in America had made great strides and American cotton entered the English market in 1750 as a competitor to Indian cotton. English manufacturers preferred the American cotton because of its quality. While the industry was at its peak, however, Britain's relations with America became strained and she had once again to fall back upon India for its supplies of cotton. Thirty million lb. were imported, but as the cotton did not suit the requirements of the British manufacturers, only 1.25 million lb. were used by them and the rest re-exported to the Continent. This acted as a damper on further imports, even during the American War. With the revival of demand thereafter, the imports of Indian cotton rose to 90 million lb. by 1816. The prices rose during 1817-19 and in 1818, 86 million lb. of Indian cotton were exported. The Indian exports reached 80,000 bales in 1829 and dropped to 35,000 bales in the following year, the prices having fallen below 6d per lb. The trade fluctuated with changing prices and in 1836, exports reached a new high of 2,19,000 bales, with the average price of Upland cotton at 10½d per lb. It rose further to 2,75,000 bales in 1839. Because of the heavy fall in prices to as low as 2½d per lb. in the early forties imports into England dropped to 95,000 bales in 1846 but, with the subsequent rise in prices, stepped up to 2,20,000 bales in 1847. By 1860, the imports of Indian cotton rose to 4,22,000 bales which was 12 per cent. of the total imports, against 82 per cent. of American cotton. In 1862, the proportion was 71 and 7 per cent., respectively. In 1867 and 1868, the exports of Indian cotton were 1.35 and 1.37 million bales, respectively, being 42 per cent. of the total imports in this two year period, about the same as the American cotton. By the end of the 19th century, however, England ceased to be an important buyer of Indian cotton.

Meanwhile, the trade between India and the Continent had also been developing. In the early years, it took largely the form of supplies diverted from Great Britain. In 1868, exports of Indian cotton to the Continent amounted to 7,20,000 bales (of which 5,50,000 bales were diverted through Great Britain) forming 47 per cent. of the total exports to Europe. By this time, direct dealings with India had started and the number of foreign mercantile houses in Bombay had increased. A French House purchased land and set up full presses in the Berars and established a French Bank at Bombay to facilitate trade with the Continent. Indian cotton was also shipped regularly to Russia, Austria, Belgium, Germany and Italy. Between 1885 and 1891, Europe was the biggest consumer of Indian cotton.

The trade with China started sometime about 1770 and that country was an important buyer of Indian cotton up to the American Civil War. Japan came into the market in 1890 and by 1897 was the biggest consumer of Indian cotton. Japan maintained this position for about 40 years thereafter, and in the closing year of that period exports to that country formed 50 per cent., of the total exports from India.

The Indian cotton mill industry started about 1854 and made steady progress. Several textile mills soon sprang up in Bombay and other centres. This new industry began to absorb an increasing proportion of the cotton produced in the country. The relative position of Indian mill consumption and exports during the four quinquennia ending 1900 is given in Table 49.

TABLE 49. MILL CONSUMPTION AND EXPORTS OF INDIAN COTTON DURING 1880-1900

Quinquennia	Average annual Mill consumption	 Exports
	(thousand bales of 392 lb.)	
1880—1885	472	1,533
1885—1890	811	1,492
1890—1895	1,216	1,395
1895—1900	1,264	1,342

Unlike the other cotton growing countries, India had a wide range of cotton from short and medium to long staple, and, on account of the wide climatic variations between the north and south of the country, there was a cotton crop ready for sale practically throughout the year. These two factors helped to make Indian cotton very popular in most cotton manufacturing countries of the world. Most of the exports were from Bombay and the trade was largely in the hands of the Europeans.

During the quinquennium ending 1906-07, the average annual production of cotton was of the order of 3.7 million bales, about 75 per cent. of which consisted of short staple cotton (below 7/8″). Roughly half the crop was consumed in the country and the other half was exported. The following 15 years witnessed a steady increase in production, mill consumption and exports. The bulk of the crop continued to be of the short staple variety. The statistical position during the First World War and the quinquennia before and after it was as given in Table 50.

TABLE 50. PRODUCTION, MILL CONSUMPTION AND EXPORTS OF INDIAN COTTON DURING 1909-23

Quinquennia	Average annual Production	 Mill consumption	 Exports
		(thousand bales of 392 lb.)	
1909-10 to 1913-14	4,270	2,026	2,614
1914-15 to 1917-18	4,374	2,146	2,124
1918-19 to 1922-23	4,587	2,094	2,565

During this period, Japan emerged as the most important buyer of Indian cotton. Her share of the total exports rose from 21 per cent. in 1903-04 to about 50 per cent. in 1913-14, which position she continued to retain for over two decades.

In 1920, one-third of the total Indian growth consisted of medium and long staple cotton (7/8″ and above) while the rest was of short staple cotton.

The medium and long staple varieties were consumed by Indian mills and the bulk of the short staple cotton was exported. With the expansion of the Indian mill industry, the demand for medium and long staples began to increase. In fact, India had already started importing long staple cotton from America in small quantities. America had increased her production very considerably and had captured a large proportion of the world trade in cotton. Immediately after the First World War, India had also appreciably increased the production of cotton to cope with the boom that followed the War. However, when the great depression started in 1929, India was left with a very large surplus and Japan as the principal buyer. Consequent on the depreciation of the yen in 1932, Japanese textiles began to flood the Indian market, causing serious embarrassment to the Indian textile industry. In August of that year, the duty on non-British piecegoods was raised to 50 per cent. As this did not check the Japanese imports, the Indo-Japanese convention of 1909 was terminated in June, 1933 and simultaneously the duty on non-British imports was raised further to 75 per cent.

These measures resulted in the Japanese boycott of Indian cotton. The impact of the boycott was felt in the following year and negotiations for a trade pact resulted in the Indo-Japanese Trade Agreement in 1934. The agreement which was for a three-year period, provided for an export of one million bales of Indian cotton against imports of 235 million yards of Japanese piecegoods, with adjustment for the increased or decreased offtake of Indian cotton. In this way, the trade with Japan was smoothed out during the subsequent years. The exports of Indian cotton to Japan reached a record figure of 2.4 million bales in 1936-37 accounting for 56 per cent. of the total exports, which had also touched the record figure of 4.27 million bales.

It became clear in the years following the First World War that India must make earnest efforts to improve the quality of the cotton crop, increase the production of long and medium staple varieties to meet her own requirement, and those of the United Kingdom and reduce her dependence on foreign markets for her surplus. On the recommendations of the Indian Cotton Committee, which was appointed in 1917 to examine and report on the question, the Indian Central Cotton Committee was established in 1923 and was provided with adequate funds for financing research schemes in all the important cotton growing areas of the country. This resulted in a steady improvement in the character of the Indian crop. The position in regard to the character of the cotton crop and exports when the Second World War broke out, was as given in Table 51.

Within a year of the outbreak of the Second World War, export of cotton from India declined sharply, due to the loss of markets in Europe and the Far East. With export outlets more or less completely cut off, Indian mills became virtually the only buyers of Indian cotton. Exports from India

Table 51. Production, Mill Consumption and Exports of Indian Cotton during 1923-24 and 1934-39

Year (ending 31st August)	Production (official estimates)				Mill consumption			Exports
	Long staple	Medium staple	Short staple	Total	Indian	Foreign	Total	
	(thousand bales of 392 lb.)							
1923-24	664	1,225	3,378	5,267	1,873	84	1,957	3,561
1934-35	472	1,066	3,226	4,764	2,665	522	3,187	3,179
1935-36	569	1,730	3,568	5,867	2,735	514	3,249	3,785
1936-37	720	1,852	3,662	6,234	2,687	524	3,211	4,354
1937-38	651	1,654	3,417	5,722	3,061	677	3,738	2,143
1938-39	627	1,793	2,631	5,051	3,215	674	3,889	3,435

were mainly of the short staple variety and the production of such cotton was much in excess of domestic requirements. A drastic curtailment in the acreage under cotton was necessitated by War-time conditions and large areas which previously grew cotton had of necessity to be diverted to the production of food crops. As a result, there was a considerable reduction in the area under short staple cotton. During the War, however, the Indian mill industry had expanded very considerably, and India became the arsenal for the Far East and Middle East theatres. The consumption of cotton by Indian mills increased very considerably and the demand for medium and long staple cottons was very great.

With the cessation of hostilities and the easing of the shipping position, the export demand for Indian cotton began to revive. The licensing system introduced during the war period was abolished in December, 1945, to facilitate the clearance of stocks of short staple cotton which had accumulated during the War and to recapture the export markets. A good demand for Indian cotton from the European countries followed and as a result prices shot up in the first quarter of 1946. To arrest the inflationary trend in prices and to conserve stocks to meet the growing demand for cloth and yarn within the country, the licensing system was re-introduced from April, 1946, and export of Indian cotton 13/16″ and above in staple was prohibited.

On account of the considerable demand for Indian cotton from China, the prices ruled high and continued to soar in July and August of that year. Apprehending an unfavourable reaction on cloth prices, a quantitative restriction was imposed in August, 1946, on exports. These were confined to two lakh bales of cotton stapling 11/16″ and below during the period September-December, 1946, comprising Bengal Desi, Sind Desi, Oomra Desi, Mathio, Dholleras (including Kalagin), Red Cocanada and Assam Comilla varieties. This had the desired effect of arresting the upward trend in prices of staple varieties of Indian cotton. This quota was over and above the quantity of three lakh bales agreed to for export to Japan on a Government to Government basis. In October, 1946, a quota of five lakh bales was announced for export during January-April, 1947. An export duty of Rs. 20 per bale was levied in order to reduce the incidence of higher external prices on the internal prices. As a result, the prices of short staple cotton began to shoot up and at one time it was feared that the stocks available would not be sufficient to meet the export demand. With a view to bringing about a reduction in the prices of short staple cotton, the export policy for the period January-April, 1947, was revised towards the end of January, 1947, and export of short staple cotton was limited to 2.5 lakh bales, while the export of the balance of 2.5 lakh bales was limited to four specified medium and long staple cottons (Jarila, L.S.S., 4F and N.T.). Meanwhile, the demand from China had fallen off; the large arrivals of the new crop, the tight monetary position and scarcity of godowns in Bombay and Karachi caused a depressing effect on the market. Consequently, distributional quotas hitherto in force were abolished and Broach, Westerns and Surats were also permitted for export.

In March, 1947, a quota of eight lakh bales was allowed for export during the May-August period, consisting of three lakh bales of short staple cotton, 2.5 lakh bales of medium staple cotton (4F, Jarila, Broach, and Westerns) and 2.5 lakh bales of long staple cotton (N.T., L.S.S. and Surats). In view of the easier supply position, all restrictions on the export of cotton during 1946-47, were removed as a temporary measure in June, 1947.

The position at the end of the period prior to the partition is indicated in Table 52.

TABLE 52. PRODUCTION, MILL CONSUMPTION AND EXPORTS OF INDIAN COTTON DURING 1939-47

Year (1st September to 31st Aug.)	Production (official estimates)	Consumption of Indian cotton by Indian mills	Consumption of all cotton (Indian and foreign) by Indian mills	Exports of Indian cotton
	(thousand bales of 392 lb.)			
1939-40	5,009	3,112	3,680	2,396
1940-41	6,204	3,691	4,251	2,055
1941-42	6,350	3,869	4,436	891
1942-43	4,798	4,391	4,855	163
1943-44	5,365	4,198	4,832	391
1944-45	3,569	4,245	4,888	417
1945-46	3,512	3,959	4,563	1,056
1946-47	3,639	3,229	3,937	1,026

Partition and Aftter. During the period of the Second World War and thereafter prior to the partition, the export policy was mainly influenced by the need : (*i*) for maintaining adequate stocks to meet the requirements of the mills in India; (*ii*) for maintaining adequate floating stocks with the trade to achieve internal price stability necessary for stabilising the prices of mill-made cloth and yarn; (*iii*) for maintaining exports of the qualities and quantities of cotton surplus to the requirements of the Indian mill industry; and (*iv*) for regulating exports of Indian cotton to maintain pre-War trade channels and pre-War overseas markets. On the partition of the country, however, India lost access to some 10 lakh bales of long and medium staple cottons grown in the West Punjab and Sind, now parts of Pakistan.

The effect of this soon began to be felt, in that the demand for such cotton from mills in India was much in excess of the available supply. Export policy had, therefore, to be revised and steps taken for increasing cotton production within the country both by intensive and extensive methods. Exports had of necessity to be restricted to shorts taple cotton comprising Bengal Desi, Oomras, Dholleras, Mathio and Assam/Comilla varieties which were surplus to Indian mill requirements. In addition, as a stablishing measure, the export duty on cotton was adjusted from time to time to bridge the gap to some extent between the prices of the exportable varieties of Indian cotton and comparable varieties from other areas in the world markets. In view of the short crop in 1948-49, caused by unfavourable weather conditions, the cotton supply position caused considerable concern and in March, 1949, export of Indian cotton was banned except to hard currency countries.

One of the major factors affecting cotton supplies during 1949-50 was the devaluation of the Indian rupee in September, 1949. However, the decision of the Government of Pakistan at that time, not to devalue the Pakistan rupee, made the cotton grown in Pakistan dearer to India. Thus, the imports of Pakistan cotton ceased altogether. The situation was met by increasing imports form other countries, which amounted to 12,52,000 bales in 1949-50. Meanwhile, a campaign had started in 1950-51 for increasing the production of cotton in India, particularly of the long and medium staple varieties which were much in demand by the Indian textile industry. The cotton export policy depended thereafter on the crop of each season. Table 53 illustrates the position in regard to cotton in India during the period 1947-48 to 1953-54.

The efforts made under the Grow-More-Cotton campaign to meet the expanding requirements of Indian mill industry began to bear fruit and the year 1954-55 saw a record crop. The export policy was liberalised both as regards quality and quantity. Accordingly 5,51,000 blaes of cotton were released for export during the season. Cotton of staple length 3/4″ and below and some stapling 25/32″ and 26/32″ were allowed to be exported. With a view to promoting larger sales in foreign markets, the export duty on Bengal Desi was raised from Rs. 125 to Rs. 150 per bale and that on other exportable varieties reduced from Rs. 200 to Rs. 150 per bale, in November, 1954. In July, 1955, the duty was lowered to Rs. 125 per bale. However, following

Table 53. Production, Mill Consumption and Exports of Indian Cotton during 1947-54

Year (1st September to 31st August)	Production (official estimates)				Mill consumption			Exports
	Long staple	Medium staple	Short staple	Total	Indian	Foreign	Total	
	(thousand bales of 392 lb.)							
1947-48	319	1,124	745	2,188	2,864	1,347	4,211	800
1948-49	322	899	556	1,767	3,124	1,131	4,255	299
1949-50	550	1,332	746	2,628	2,544	1,141	3,685	223
1950-51	684	1,448	839	2,971	2,517	1,105	3,622	176
1951-52	918	1,223	992	3,133	2,987	1,084	4,071	200
1952-53	900	1,366	865	3,131	3,611	849	4,460	309
1953-54	1,365	1,623	947	3,935	3,860	753	4,613	134

the devaluation of the Pakistan rupee towards the end of that month, the duty was further reduced to Rs. 50 per bale in August, 1955.

In 1955-56, the licensing system was modified and export licences were granted to established shippers and new-comers. A quantity of 4,25,000 bales was allowed for export during the season, of which 95,000 bales were Bengal Desi, 3,00,000 bales of staple length 3/4″ and below, 25,000 bales of 25/32″ staple and 5,000 bales of Red Cocanada. In addition, Assam/Comillas, Zoda (cotton of third picking and having no spinnable value) and Yellow pickings were freely licensed for export. In 1956-57, 4,00,000 bales were allowed for export, but in view of the crop damage and the anticipated tight supply position, exports were banned with effect from the 30th March, 1957 During 1957-58, 3.4 lakh bales were released for exports. The position as at the end of 1957-58 season is indicated in Table 54 (Fig. 35).

Table 54. Production, Mill Consumption and Exports of Indian Cotton during 1954-58

Year (1st September to 31st August)	Production (official estimates)				Mill consumption			Exports
	Long staple	Medium staple	Short staple	Total	Indian	Foreign	Total	
	(thousand bales of 392 lb.)							
1954-55	1,529	1,908	790	4,227	4,124	646	4,770	319
1955-56	1,577	1,781	662	4,020	4,326	614	4,949	612
1956-57	2,018	1,960	767	4,735	4,648	569	5,217	299
1957-58	1,982	1,926	845	4,753	4,433	566	4,999	308

In 1958-59, a quantity of five lakh bales was permitted for export in two instalments each of 2.5 lakh bales, comprising 2.5 lakh bales of Bengal Desi, 2 lakh bales of cotton other than Bengal Desi stapling not above 3/4″ and 50,000 bales of cotton other than Bengal Desi below 3/4″ in staple. The exports of Assam/Comillas, Zoda, Yellow pickings are free, i.e., licensing no longer required. With effect from the 16th November, 1958, the export duty was reduced to Rs. 25 per bale. Licences for exports are issued on a first-come-first-served basis, subject to a maximum of 10 per cent. per shipper from all ports, of the quantity available for exports, after reserving 15 per cent. of the quota for co-operative societies.

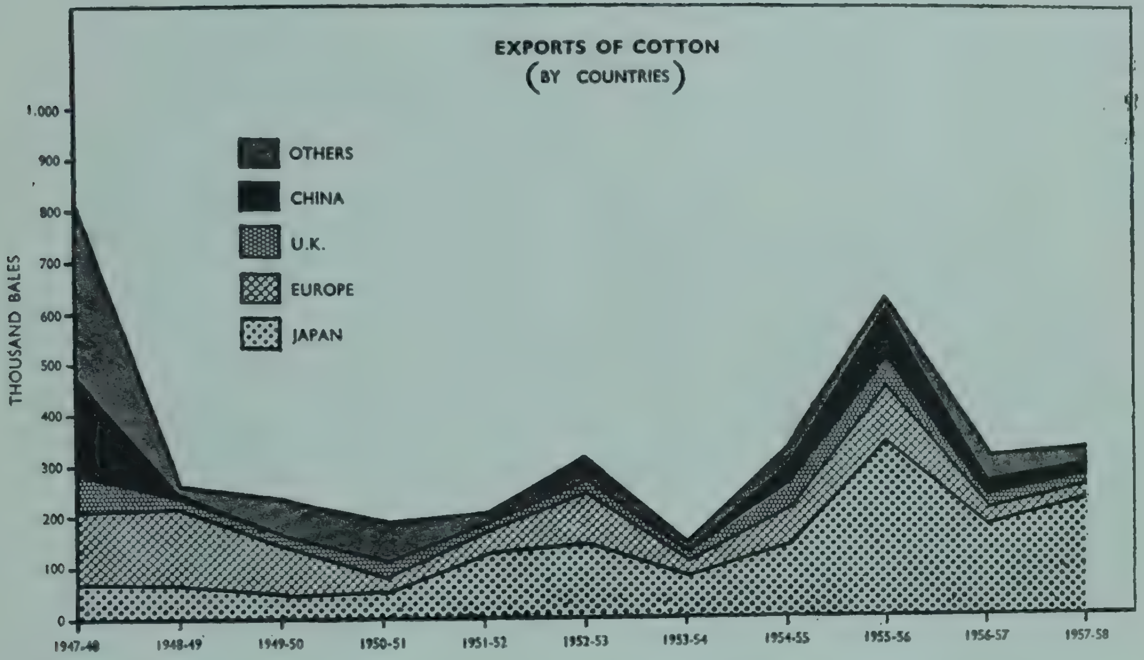

Fig. 35. Countrywise Exports of Cotton

IMPORTS

Simultaneously with the expansion of the Indian mill industry, the demand for medium and long staple cotton began to increase and small quantities of long staple cotton were imported from America. Such imports were negligible until 1920. In 1920-21, 81,000 bales of superior American cotton were imported. Since then there has been an increase in imports of long staple cotton, the chief sources being Egypt, the Sudan, British East Africa and the United States. In 1938-39, 5,80,000 bales were imported comprising 98,000 bales from America, 1,29,000 bales from Egypt and 3,53,000 bales from other countries, mainly British East Africa. During the Second World War, there were difficulties in regard to the import of foreign cotton and special efforts were made to import cotton in order to keep the mill industry working not only for its own sake but also for providing the cloth required for the armed forces. Such imports during this period were about five lakh bales per annum, on an average, mainly from Egypt, the Sudan and British East Africa and imports from the United States dwindled. Imports rose to six to seven lakh bales in 1946-47.

After the partition, India lost access to about 10 lakh bales of long and medium staple cottons grown in the areas included in Pakistan. Pakistan cotton was imported for utilisation in Indian mills. The short crop in 1948-49 caused considerable concern in the cotton supply position and made it difficult to maintain production of yarn and cloth at the then existing levels. During the season, an agreement for a bulk purchase of East African cotton was concluded and through a trade agreement India secured a supply of three lakh bales of Egyptian cotton. When the Pakistan rupee was not devalued along with the devaluation of the Indian rupee, imports of Pakistan cotton ceased altogether in 1949-50. Supplies were then augmented by imports from the United States and East Africa. The 1950-51 season was exceptionally difficult in so far as import of foreign cotton was concerned and India had to cover her requirements in world markets at runaway prices. The position remained static in 1951-52. In 1952-53, however, the internal availability of cotton in India became easy for the first time since the partition of the country. The results of efforts made to increase both the overall production of cotton and the production of superior long and medium staple cottons were satisfactory and encouraging, and India is now self-sufficient in regard to cottons of staple length up to 1-1/16″. From July, 1953, imports of cotton of staple length 1-1/16″ and above only have been permitted. Since 1955-56, the import of U. S. cotton was governed by the P.L. 480 and P.L. 665 and under the Indo-Burma-U.S. Tripartite Agreement, i.e., import of cotton by India in exchange for export of Indian textiles to Burma. Import of Egyptian cotton is under the Special Payments Procedure. Import duty was abolished with effect from the 28th February, 1954.

Table 55 shows the imports of cotton from different countries during the period 1947-48 to 1957-58 (Fig. 36).

TABLE 55. IMPORTS OF FOREIGN COTTON DURING 1947-58

Year (1st September to 31st August)	Imported from						Total
	Egypt	Sudan	East Africa	U. S. A.	Pakistan	Others	
	(thousand bales of 392 lb. each)						
1947-48	247	90	174	17	554	18	1,100
1948-49	455	37	184	13	323	66	1,078
1949-50	348	63	289	493	12	47	1,252
1950-51	253	72	217	365	5	19	831
1951-52	147	53	135	890	—	15	1,240
1952-53	255	79	252	86	—	5	677
1953-54	263	45	183	190	—	10	691
1954-55	143	79	287	93	—	12	614
1955-56	214	130	234	10	—	22	610
1956-57	53	70	115	352	—	18	608
1957-58	68	74	112	143	—	1	398

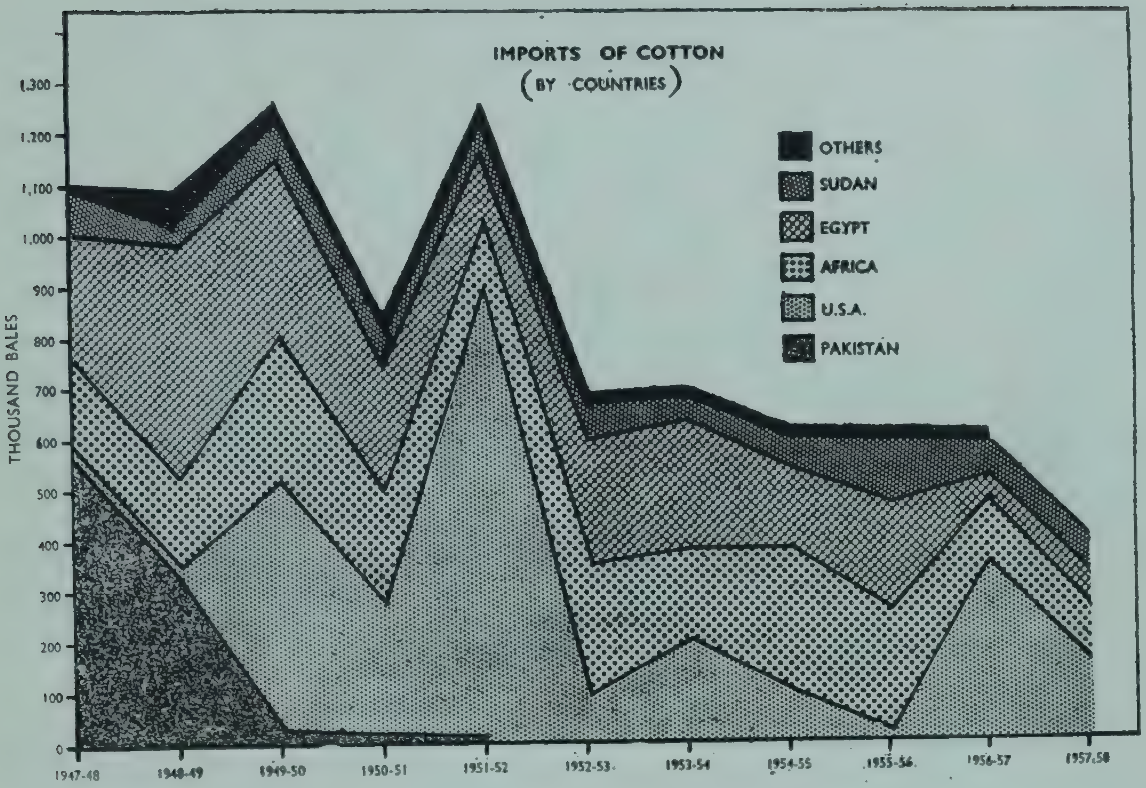

Fig. 36. Countrywise Imports of Cotton

In 1958-59, the following quantities have been announced so far for import :

1. 10,000 bales 1-1/16″ and above in staple from Soft Currency areas.
2. 20,000 bales 1-3/16″ and above in staple from Egypt, the Sudan, Peru and Uganda.
3. 95,000 bales 1-1/16″ and above in staple under U. S. Aid Programme (P.L. 480).
4. 1,40,000 bales 1-1/16″ and above but below 1-3/16″ in staple from any country.
5. 55,000 bales 1-3/16″ and above in staple from any country.

With a view to promoting exports of cotton textiles, half the quantity mentioned under items 3, 4 and 5 above has been earmarked from import under the Export Incentive Scheme. Under the Scheme, it was announced in February, 1959, that 48,000 bales of American cotton 1-1/16″ and above under the P.L.480, 60,000 bales of 1-1/16″ and above from any country and 25,000 bales of 1-1/16″ and above but below 1-3/16″ from any country are proposed to be distributed to actual user mills. Apart from these, separate allotments of foreign cotton will be made to exporter mills against their retention entitlements, the balance being made over to the Textile Commissioner, Bombay, for distribution to actual users (Fig. 37).

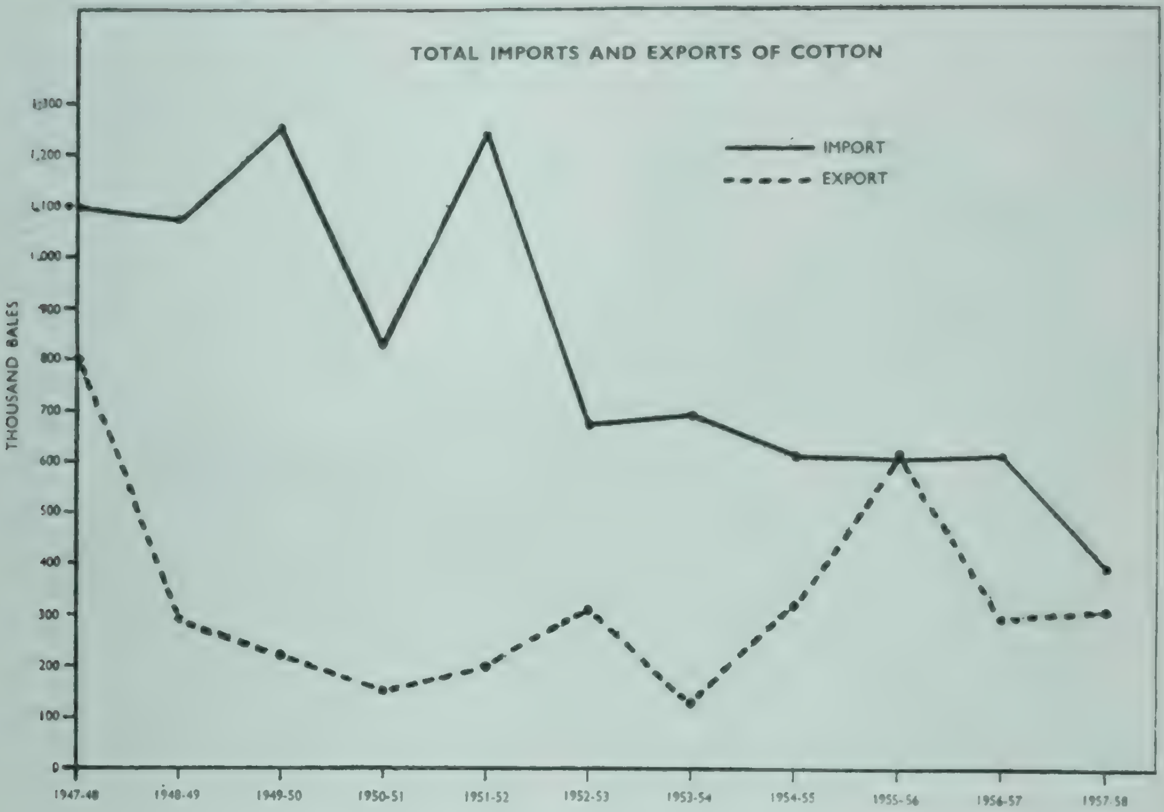

Fig. 37. Total Imports and Exports of Cotton

Future Prospects. The policy to be followed in the matter of import and export of cotton has to be determined with due regard to India's economy since Independence. Exports are permitted after conserving supplies to meet the needs of the Indian textile industry. In the initial stages, large quantities of foreign cotton had to be imported to make up the short-fall in the domestic production, which is mainly dependent on the vagaries of the monsoon. In 1958-59, for instance, the crop according to trade sources was estimated at 57 lakh bales at the beginning of the season, owing to favourable weather conditions. Since then due to excessive rainfall and floods, the crop has been scaled down to 48.9 lakh bales as at the end of March, 1959. On present indications, the mill consumption of cotton during 1958-59 is estimated to be about 52 lakh bales (47 lakh bales Indian and 5 lakh bales foreign).

India with her large and growing population represents an unlimited market for textiles and the Indian cotton textile industry has a vast field for expansion even to meet the home demand. Thus, there is great scope for increasing the production of cotton in India, particularly of the staple varieties. It is anticipated, however, that in 1960-61, the last year of the Second Five-Year Plan, the crop is likely to be around 54 lakh bales against the target of 65 lakh bales fixed under the Plan. A target of 72 lakh bales of cotton has been proposed for achievement by the end of the Third Five-Year Plan.

A significant development in the research programme of the Indian Central Cotton Committee has been the evolution of strains, viz., Indo-American, 170-Co.2 and 134-Co.2-M, in Gujerat State, M.C.U. 1 and 2 in Madras State, M.A.5 in Mysore State, Punjab-American, L.L.54, in the Punjab State and Sea Island 'Andrews' cotton in Kerala and Mysore States. The first three strains can be utilised for spinning fine yarns but are not comparable in yarn strength to similar cottons imported from the United States and East Africa for the purpose. Steps are being taken to improve the quality of these cottons. Punjab-American, L.L.54, is promising and its release for general cultivation has just been recommended. It is expected to cover an area of six lakh acres in the Ferozepore and Bhatinda districts of the Punjab and Sri Ganganagar district of Rajasthan. On the other hand, Sea Island 'Andrews' cotton has been successfully acclimatised and found suitable for growing on the hilly tracts of the West Coast of the States of Kerala and Mysore. This cotton is equal in quality to Egyptian-Karnak and suitable for spinning 70's counts. Its development is under a special scheme in operation in the two States. It is intended to cover an area of three lakh acres producing about 2.25 lakh bales by the end of the Second Five-Year Plan. Unfortunately, unfavourable weather conditions handicapped progress in 1957-58 and 1958-59. However, 206 bales have been sold by auction during 1958-59 at prices ranging from Rs. 2,800 to Rs. 3,500. No doubt, this will stimulate its rapid extension and it is hoped that, within the next five years the programme of its development will be achieved in full. On the attainment of the above objectives, it may be possible to meet the demands of the mill industry in respect of cotton for manufacturing fine and superfine yarns by indigenous production, thereby eliminating imports from abroad. Till then, however, India will necessarily have to continue to import foreign cotton to the extent of five to six lakh bales. In determining the quantum of cotton to be imported from time to time, therefore, the overall requirements of the industry, production within the country, the production and price trends abroad and the balance of payments position will need to be taken into account. Similarly, in determining the quantity and varieties of cotton which India can afford to export, due consideration should be given to the domestic production of cotton and to the maintenance of a reasonable carry-over.

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